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U.S. Armed Forces. NRC Vision Committee

Weekly Inv

MINUTES AND PROCEEDINGS

of the sixteenth meeting of the

ARMY - NAVY - NRC VISION COMMITTEE

25-26 June, 1946

National Academy of Sciences
2101 Constitution Avenue
Washington, D.C.

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ARMY-NAVY-NRC VISION COMMITTEE
MINUTES

Sixteenth Meeting
National Academy of Sciences
2101 Constitution Avenue
Washington, D.C.
25-26 June, 1946

The following were present:

ARMY	AAF	Major E. A. Pinson Captain Gerald Fonda, School of Aviation Medicine, Randolph Field, Texas
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Dr. Selig Hecht
Dr. Walter Miles
Dr. George Wald

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Dr. Lloyd H. Beck, Yale University
Dr. F. S. Brackett, Nat'l Institute of Health, Bethesda Md.
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Lt. Comdr. George Dyson
Dr. Irvine C. Gardner
Dr. I. H. Wagman, Johnson Foundation, University of Pennsylvania
Dr. L. J. Milne, Johnson Foundation, University of Pennsylvania
Dr. Carl Miller, Brown University
Dr. Frederick K. Reid
Dr. John H. Sulzman
Dr. Donald G. Marquis
Mr. H. Richard Blackwell

Tuesday, 25 June, 1946

1. The Chairman called for corrections or alterations in the Minutes and Proceedings of the 15th meeting. There were no corrections.

2. Dr. H. K. Hartline, Dr. I. H. Wagman, and Dr. L. J. Milne presented a series of papers entitled "Physiological Factors Determining the Performance of Binoculars at Night"- - - - - - - - - - - - - - - - - - 13

3. Dr. George Wald presented a paper entitled "Factors Affecting the Change of Focus of Optical Instruments at High and Low Illuminations"- -19

4. Lt. W. S. Verplanck presented a paper entitled "A Brief Report on Results of the Field Experiment on Optical Instruments"- - - -23

5. Dr. Howard S. Coleman presented a paper entitled "The Contrast Rendition of Optical Instruments"- - - - - - - - - - - - - - - - - 29

6. The Chairman requested that the Subcommittee on Binoculars meet and return to the Committee a recommendation concerning a mechanism for coordinating the knowledge on binoculars.

Wednesday, June 26, 1946

7. The Chairman presented the following resolution prepared by the Subcommittee on Binoculars, which was approved by the Committee:

VOTED: It is the opinion of this Subcommittee that the studies already made provide a basis for the determination of optimum characteristics of telescopic optical instruments, provided that this information is properly collated. (1) It seems appropriate to us that Dr. Coleman be invited to undertake this collation. (2) It likewise appears desirable to us that Dr. Verplanck be encouraged to continue the analysis of the New London data, so that this valuable material may be used to fullest advantage. (3) It is our further recommendation that advisory assistance be rendered to the Navy under the auspices of the Army-Navy-NRC Vision Committee by all individuals who have been associated with this work.

8. Dr. F. K. Reid presented a paper entitled "Correction of Refractive Errors by Training"- 33

9. Dr. Richard Tousey presented a paper entitled "The Effect of Spectacle Lens Power on Point Source and Visual Acuity Thresholds"- -36

10. Dr. Franklyn D. Burger presented a paper entitled "Report on Recent Studies of Acuity in the Mesopic Brightness Range in Relation to Refractive Error"-(Paper will be published at a later date)

11. Lt. Comdr. Dean Farnsworth presented a paper entitled "Current Studies in Color Vision" - 43

12. The Chairman called for discussion of the proposal for a vision research center to be established in the Navy Department under the Office of Research and Inventions. A memorandum, prepared by Lt. W. S. Verplanck, concerning the proposal is presented in the Proceedings- 49
After discussion, the following resolution was passed:

RESOLVED: That the Army-Navy-NRC Vision Committee endorses the establishment, within ORI, of a Vision Research Center, to provide a central establishment for vision research within the Navy and to implement service requests and recommendations of the Vision Committee.

13. The Chairman called for action by the Committee in preparing a program for research in the field of vision. After a discussion, the following individuals were appointed to serve as subcommittees-of-one to draw up a research program in each of the specified fields:

Color Vision -- Lt. Comdr. Dean Farnsworth
Night Vision -- Lt. W. S. Verplanck
Illumination -- Space: Major E. A. Pinson
Special: Major E. A. Pinson
Projection: Mr. Morris Smith
Visibility -- Mr. H. Richard Blackwell
Legibility & Location of Instruments -- Lt. Col. Paul Fitts
Visual Functions -- Lt. Comdr. Henry A. Imus
Optical Equipment -- Dr. Howard S. Coleman
Protective Equipment -- Dr. Alphonse Chapanis

14. The Chairman asked that the Minutes of the Executive Committee meeting on May 28 and June 25 be read into the Minutes of the present meeting.

At the May 28 meeting, it was voted that officers of the Vision Committee be elected by the Executive Committee on or about January 1, 1947. It was voted further that in the interim period, the present officers, Captain Shilling and Commander Dyke retain their offices. It was voted that terms of office of the elected members of the Executive Committee be fixed as follows:

January 1, 1948	January 1, 1949
Major E. A. Pinson	Dr. Edwin Henry
Commander H. G. Dyke	Captain C. W. Shilling
Dr. Walter R. Miles	Dr. Selig Hecht

At the June 25 meeting, Procedures for the Operation of the Vision Committee were adopted. A statement of the procedures is presented in the Proceedings- -54

15. The Chairman asked that Vision Committee Staff reports be read into the Minutes of this meeting. The texts of the reports are presented in the Proceedings.

A. "Design for an Illumination System for the Mark V Surface Lookout Alidade"- -57

PHYSIOLOGICAL FACTORS DETERMINING THE PERFORMANCE OF BINOCULARS AT NIGHT

Dr. H. K. Hartline, Dr. I. H. Wagman, Dr. L. J. Milne
Johnson Foundation, University of Pennsylvania

(These reports summarize the material contained in OSRD Report No. 6099, October 31, 1945, which is now declassified)

An attempt has been made to integrate recent laboratory studies of the effectiveness of binoculars at night with investigations conducted to determine the probable physiological mechanisms involved in the use of binoculars. The various research projects reported herein were conducted under the general supervision of NDRC Section 16.1. Laboratory tests of the increase in target visibility with various service binoculars at night have been reported in OSRD Reports No. 4433 and No. 6128, representing the Dartmouth College and the Brown University projects, respectively. The investigations concerned with problem of physiological mechanisms were conducted by the Johnson Foundation and are to be found in OSRD Reports No. 6098 and No. 6099.

The two general kinds of physiological factors involved in the effectiveness of binoculars at night are: (1) the effect on visual functioning produced by unsteadiness in holding the instruments, and (2) the effect on visual functioning produced by light loss. An experiment conducted at the Johnson Foundation indicated that only these two factors were present in the Brown laboratory tests of binoculars. It was shown that when unsteadiness of holding was completely eliminated, thresholds were obtained with binoculars completely in accordance with threshold predictions based upon the increased magnification and the loss in brightness produced by the instrument.

A method was developed by which the visibility of targets through binoculars could be computed from naked eye observations assuming complete elimination of unsteadiness of holding. In order to make this computation, the retinal illumination with a given binocular was computed, utilizing data for the transmission of light through binoculars and data for the size of the limiting aperture of the optical system. Measurements of the transmission of optical instruments were made by visual photometry. The size of the limiting aperture was established by determining whether the exit pupil of the binocular or the pupil of the eye was the smaller aperture. Data for the pupillary diameter at various levels of surrounding brightness were taken from the extensive British study (ARL.N2/0.502, April 1942) and from OSRD Report No. 6098. Proper allowances having been made for the limiting aperture and for the loss in brightness in the binocular, retinal illumination can be computed for any binocular under specified viewing conditions. (Because

of the small-angle surround utilized, there was no appreciable contrast reduction in the binocular tests at Dartmouth and Brown.

In order to evaluate the visibility of targets once the retinal illumination is known, interpolations must be made from the naked eye data reported by Brown University. A special system of interpolations based upon theoretical equations has been developed. By this procedure, the relative visibility of objects seen by the naked eye and seen through a specified binocular can be predicted.

Unsteadiness of holding has been shown to consist of two effects: (1) misalignment between the exit pupil of the binocular and the pupil of the eye, and (2) angular tremor. Experiments at the Johnson Foundation indicate that the loss in efficiency due to unsteadiness is divided about equally between the two effects. Misalignment errors were measured by infrared photography. In addition to the error produced by incorrect I.P.D. adjustment or other incorrect positioning, it was found that the movement of the eyes during scanning of the binocular field causes unexpectedly large brightness losses because of "clipping". The magnitude of angular tremor was measured both in the laboratory and at sea by photographing a light projector mounted upon the binocular, or by photographing a point of light mounted in the field with a camera mounted on the binoculars. It was found that angular tremor under field conditions was often two or three times as large as that obtained in the laboratory.

An attempt was made to ascertain whether the effect of tremor could be explained using naked eye observations as follows: It was assumed that temporal summation in the retina was complete. In this event, the effect of angular tremor would reduce to the increase in the area of the retinal image. Naked eye observations demonstrate that if the same target flux is distributed over a larger area of the retina, there is a resulting loss in efficiency due to imperfect spacial summation. An attempt was made accordingly to predict the loss of efficiency resulting from angular tremor on the basis of the loss in efficiency resulting from increase in image size. It was discovered that if an angular tremor be assumed commensurate with that measured in the laboratory, in many cases the effect of tremor could be predicted by the existence of reduced spacial summation.

In general, the analysis has indicated that if allowance is made for the retinal illumination and for the enlarged size of the target image resulting from tremor, good agreement can be obtained between laboratory data with the naked eye and laboratory data with binoculars. Misalignment errors are always present, of course, and inclusion of an allowance for this factor in the analysis serves to reduce the amount of

tremor which must be assumed to explain the loss in efficiency obtained in the laboratory. The analysis appears satisfactory in many cases to explain completely binocular effectiveness. It was pointed out that theoretical considerations do not explain the experiments reported by Brown University on the effectiveness of exit pupil size. Furthermore, the Dartmouth data remain somewhat anomalous in that these binocular results can be predicted completely by assuming perfectly steady holding and allowing only for the brightness losses in the instruments.

DISCUSSION:

Dr. Wald commented that the discussion of binoculars was applicable only to night use since different problems exist at high intensities. He emphasized that retinal illumination is no longer critical in the daytime since visual functions do not undergo change with large reductions in the retinal illumination. He raised the question whether a different set of factors would be involved if a visual acuity problem rather than a light detection problem had been used.

Professor Miller interjected the thought that laboratory tests at Brown indicated radical changes in the performance of binoculars as field brightness was increased to the twilight zone. Under these circumstances, there seems to be an increase in detection because of the motion of the target image on the retina produced by angular tremor.

Dr. Hartline mentioned that in assuming temporal summation at low brightness, he had taken into account the "action time" of the retina, using approximately 1/5 second for low brightnesses. It is known that the action time becomes smaller at high brightnesses.

Professor Miller remarked that there is apparently a difference in the retinal units utilized with the naked eye and with binoculars. In the twilight region, observers apparently rely upon the rods with binoculars and the cones with the naked eye. This obviously reduces the effectiveness of binoculars in the twilight brightness region. This conclusion was reached as the result of an experiment in which a small red target was used. With binoculars, the target looked white, whereas with the naked eye it was seen as red.

Professor Hardy commented upon the effectiveness of binoculars in the daytime and emphasized that the atmosphere is most likely the limiting factor under these

circumstances. He referred to his publication in the May issue of the Journal of the Optical Society of America which demonstrates this point.

Professor Hardy made the interesting suggestion that a Galilean telescope might prove extremely valuable for military purposes because of the ease with which the eye can be properly positioned. He suggested that it might be feasible to develop a large field Galilean at the expense of adequate correction at the edges of the field. He believed that observers might be trained to move the binocular with the head so that the eye would always utilize the corrected center of the field. In this way, the known disadvantages of the Galilean might be avoided and the problem of positioning binoculars correctly might be eliminated.

Professor Miller expressed the opinion that such a Galilean telescope might be extremely effective for night vision.

Dr. Beck, in attempting to explain the Brown exit pupil series, remarked that there may have been less angular tremor at Brown than would have been expected because the observers were told to consider the eye, head, and binocular as a "functional unit". If this were the case, the increase in exit pupil would not produce as much effect as Hartline would expect because the binocular would be positioned correctly even with the smaller exit pupils. (However, the increase in retinal illumination with increase in exit pupil should still produce an increased visual efficiency which was not apparent in the Brown results).

Professor Miller reported studies at Brown University concerning the relative effectiveness of monocular and binocular vision. He reported that the addition of the second eye was more effective with naked eye than with binocular settings. He attributed this to the difficulty of proper alignment experienced with binoculars.

Dr. Brackett cautioned the group against extending the conclusions reached to problems in which binoculars are used for visual tasks other than mere light detection. He emphasized the great usefulness of high powered optical instruments in recognition of detail of military targets.

Mr. Blackwell asked whether it was possible to explain the Dartmouth results in any conceivable way.

Dr. Beck thought the better performance at Dartmouth might be explained by the fact that no scanning procedure was used. Experimental work at Brown in which scanning was involved indicated substantially higher binocular gains.

Dr. Wald pointed out that monocular trials should approach theoretical expectations more closely than binocular trials. In the use of binocular instruments, changes in accommodation result in changes in convergence which produces a change in the interpupillary distances. Since this deviation results in misalignment of binoculars, there is a subsequent loss in efficiency.

Dr. Wald expressed himself in favor of the kind of binocular developed by the Johnson Foundation, whose center of gravity was in the head of the observer.

Dr. Hartline regretfully stated that the binocular so constructed did not perform satisfactorily in the field tests at New London.

Professor Miller emphasized that the particular binocular was at fault rather than the design.

FACTORS AFFECTING THE CHANGE OF FOCUS OF OPTICAL INSTRUMENTS AT HIGH AND LOW ILLUMINATIONS

Dr. George Wald and Dr. Donald R. Griffin
Biological Laboratories of Harvard University, Cambridge
(This material is now declassified)

During the war it was reported from a number of sources in this and other countries that the human eye behaves as though relatively short-sighted in dim light, and that for this reason observers tend to set optical instruments more negatively in dim than in bright light. A study was undertaken to determine the magnitude of this effect, and its causes.

The focusing of binoculars was examined in a group of 21 observers who made repeated settings outdoors and indoors, at daylight and starlight levels of illumination. In 110 series of trials the settings averaged 0.54 diopter (D.) more negative in dim light than in bright light. The differences in individual series varied widely, from -3.4 D. to +1.4 D.

Several observers regularly exhibited differences of setting in dim light much more negative than the average, ranging between -1 and -3 D. in individual series. In 5 such persons the focus settings in dim light which yielded the best visual acuity performance were determined objectively; they were found to correspond closely with the subjects' own settings.

In attempting to account for the relative myopia of the eye in dim light, three factors must be considered: (a) the opening of the pupil in dim light; (b) the shift of spectral sensitivity toward shorter wavelengths in dim light (Purkinje shift), in conjunction with the chromatic aberration of the eye; and (c) possible changes in the accommodation in dim and bright light.

The opening of the pupil appears to make no important contribution to the effect. The human eye has only a very small spherical aberration; and the measurements of Ames and Proctor, and others show that in going from a day (3 mm.) to a night pupil there is generally a slight <u>lengthening</u> of focus (hyperopia) - a change opposite in direction to the one under consideration. It is true that other factors than spherical aberration might be suspected to change the focus when the pupil is expanded. The following tests show directly, however, that all such possibilities taken together exercise no important effect: (a) No consistent differences in the focus of the eye could be found, when observations in

dim light made with the natural pupil were compared with those made with an artificial pupil 2 mm. in diameter. (b) Previous reports were confirmed that when binoculars are focussed upon bright stars at night the settings are not significantly different from those made in daylight, though the pupils are very different in size. Possible effects of chromatic aberration are excluded here by the circumstance that such star settings are foveal, and hence do not involve the Purkinje shift. (c) Binoculars were focussed in the laboratory upon a monochromatic target in bright light (central cone vision) and in light so dim as to involve only off-center rod vision. The settings in dim light averaged only about 0.1 D. more negative than in bright light. The effects of chromatic aberration were excluded in this experiment by the monochromaticity of the source. It is concluded that within the limits of accuracy of these observations, the opening of the pupil does not appreciably affect the focus.

It has been known since Newton that the human eye exhibits a very considerable chromatic aberration; it is increasingly myopic the lower the wavelength. In a new series of measurements the chromatic aberration was determined in 14 observers between 750 and 365 mμ. Over this range of wavelengths the power of the eye was found to increase on the average about 3.2 D.; about 2/3 of this change occurs between 492 and 365 mμ.

In going from foveal cone to peripheral rod vision, the maximal sensitivity of the eye shifts from about 560 to 505 mμ. Our measurements show that this change involves an increase in power of the eye of about 0.35 - 0.40 D. It may be expected therefore that optical instruments will be set this much more negatively in dim light on the basis of the chromatic aberration of the eye alone.

The observed average negativity of setting of binoculars in dim light (0.54 D.) was significantly larger than this. Furthermore, as stated above, some observers regularly exhibited differences of setting in dim light much larger than the average. Some factor in addition to chromatic aberration must operate in these instances. This was found to be involuntary accommodation.

A group of 5 observers who chose settings much more negative in dim than in bright light, and in whom this negativity of setting had been shown to correspond closely with the condition for optimal visual acuity, were treated with homatropine, or homatropine and paradrene, to paralyze the accommodation. In every case the subjects' own settings in dim light, and the objectively determined optimal settings for visual acuity, became distinctly more positive. That is, the special negativity of setting of these subjects in dim light was abolished by paralyzing the accommodation. What residual negativity of setting remained could be explained on the basis of chromatic aberration.

It is concluded that under the present conditions of measurement observers set binoculars on the average about 0.5 D. more negatively in dim than in bright light. About 0.35 - 0.40 D. of this change appears to be due to the Purkinje shift, in conjunction with the chromatic aberration of the eye. The remainder is due to involuntary accommodation in dim light. It was shown in a number of instances that the negative settings chosen by observers in dim light were close to those which yielded the best visual acuity.

*A detailed account of this work (with the same title as above) has appeared in CMR Report Number 493, 31 December 1945; and will appear shortly also in the Journal of the Optical Society of America.

DISCUSSION:

Dr. Tousey reported briefly the experiments conducted at NRL to determine the optical focus of binoculars at night. A more complete summary of this report will be found in the Proceedings for Wednesday, June 26.

Dr. Gardner suggested that part of the effect attributed to the chromatic aberration of the eye might be caused by the chromatic aberration of the binoculars. Following this discussion Dr. Wald and Dr. Griffin checked this possibility in a series of measurements with the standard 7 x 50 glasses: "It was found that the change from 560 to 505 mμ associated with the Purkinje shift would introduce a change of setting of the binoculars of about +0.05 D. on the basis of their own chromatic aberration. This is opposite in direction from the observed average change in setting in dim light and is so small as to be almost insignificant in the type of observation under discussion."

A BRIEF REPORT
ON
RESULTS OF THE FIELD EXPERIMENT ON OPTICAL INSTRUMENTS.

W. S. Verplanck, Lt. USNR

(This material is now declassified)

Since a description of the procedure followed in the field experiment on optical instruments was reported to the Committee during its February 1946 meeting, and since a full report of the results will appear in the forthcoming NavOrd 77-46, this paper will restrict itself to a straightforward presentation of results.

Since the earlier report, it has been found possible to combine the data obtained on a single instrument from the several sets of runs during which it was tested. Our final results, then, are presented in terms of Relative Range Performance curves, which give the probability that a given instrument will yield ranges of various percentages of the mean range yielded by the standard 7x50x7.1° hand-held instrument.

TABLE I

.50 RRP Values Obtained on Hand-held Binoculars.

Instrument	Night Observations: Signal Bridge .50 RRP	Night Observations: Gun Deck .50 RRP	Day Observations: All Decks .50 RRP
6x42x12°	-	95.3	100.0
7x50x7.1°	100.0	100.0	100.0
7x50x10°	-	103	102.5
8x60x7°(-1d)	105.5	103.8	-
9x63x5.7°	-	112.5	-
10x50x7.1°	106.7	117.0	100.2
10x70x7.1° (Johnson Foundation)	92.0	-	-

BASIC RESULTS:

1. 7x50x7.1° Binocular Advantage: At night, the 7x50x7.1° binocular yielded ranges approximately 2 1/2 times as great as those yielded by the naked eye. This finding conforms with that of Bushie's investigations. During day observations, 7x50x7.1° ranges averaged only 11% greater than those of the naked eye.

2. The Binocular vs. the Monocular: The 7x50x7.1° binocular yielded ranges 10% greater than 7x50x7.1° monoculars during night observations. During day observations, the monocular RRP was 99.1% that of the binocular.

3. Hand-held Binocular: Table I gives the 50% RRP obtained with hand-held binoculars. Figures IA and B give the RRP curves for the night observations from signal bridge and gun deck respectively.

TABLE II
.50 RRP Values for Mounted Binoculars.

Instrument:	Night Observations Signal Bridge .50 RRP	Night Observations Gun Deck .50 RRP	Day Observations All Decks .50 RRP
6x42x12° mtd.	- - - - Incomplete - - - - - -		
6x50x7°	91.9	-	-
7x50x7.1° mtd.	115.5	-	111.5
7x50x10° mtd.	-	106.	-
9x63x5.7° mtd.	-	120.2	-
10x50x7° mtd.	122.3	-	117.5
10x70x7° (NDRC)	119.5	-	-
10x80x7°	133.0	-	114.
20x120x3°	188.0	-	193.
25x100x3.6°	179.9	-	173.5

TABLE III
.50 RRP Values for Mounted Monoculars.

(These instruments were employed only on the Signal Bridge)

Instrument:	Night Observations .50 RRP	Day Observations .50 RRP
4x28x10°	53.0	97.2
6x30x8.5°	53.0	-
6x33x8°	64.9	100.
8x33x7°	Data insufficient	94.
16x96x3.2°	117.0	-
21x76x2.8°	79.8	93.8
24x96x2.2°	126.2	-

4. Mounted Binoculars: Table II gives the .50 RRP's of mounted binoculars, and Figure 2A and B, the RRP curves obtained during the night runs.

5. Mounted Monoculars: Table III gives the RRP of mounted Monoculars, and Figure 3 the RRP curves obtained during night runs.

6. Magnification: From the data of 3, 4, and 5 above, it appears that within the range of magnifications tested, RRP is a linear function of magnification. The empirical equations describing the relationship as determined by the method of least squares, are as follows:

(a) Hand-held binoculars, night.

$$RRP = 4.3\ M + 70.4$$

(b) Mounted binoculars, night.

$$RRP = 6.5\ M + 59.7$$

(c) Mounted binoculars, day.

$$RRP = 4.0\ M + 72.0$$

where M is equal to the linear magnification.

7. Binocular Mounts and Vibration: Figures 4A and B, and Figure 5 give the RRP of a series of hand-held and mounted binoculars obtained at the standard speed, and at a speed of 17 knots which provided maximum vibration. Careful analysis of these data, and of the actual ranges obtained, indicates that the 10x50x7.1° hand-held binocular range remains approximately constant, as do the ranges of the 7x50x7.1° binocular in various mounts. The 7x50x7.1° hand-held binocular ranges deteriorate with vibration, as do those of the hand-held 7x50x10° and 6x42x12°. The mounted 10x50x7.1° binocular RRP improves. These results are contrary to theoretical expectations, which would predict deterioration of the performance of high-powered instruments with vibration, with lower powers proving relatively advantageous.

8. Fixed Focus: An 8x50x7.1° binocular with focus fixed at -2 diopters yielded an RRP approximately 2% greater than that yielded by the same instrument used at -1 diopter. More thorough analysis of the data shows that this finding on a group did not hold for individuals. Some did substantially better with the -1 diopter focus. It is noted that the performance of an individual in these two fixed-focuses could not be related to the focus obtained by the observer when free to determine his own.

9. Head-rests: No advantage seemed to be yielded to an observer by the provision of a headrest.

10. Search: Analysis of data obtained on search for the submarine or submarine chaser shows that differences among optical instruments are substantially less when determined on problems of search than on examination of fixed targets.

11. Interaction: Of 12 observers, using three different instruments, the 7x50x7.1°, the 7x50x10° and the 10x50x7.1° hand-held binoculars, three performed best on the first, four on the second, and five on the third. The differences among observers were substantial. Analysis has not yet yielded the basis for this effect, but it is not believed that it seriously affects the results of the comparisons which have been made, since a large sample of observers was employed on each instrument.

Subjective Evaluation: Subjective evaluations of optical instruments on the basis of suitability for constant use (search) by those who have used a variety of instruments have a remarkably high validity (r = .70). However, this subjective evaluation is made not only on the basis of the instrument's utility, but also on its "ease of handling".

SECONDARY RESULTS:

Secondary analyses have been made of the ranges obtained with the standard instrument largely on one discrimination (Target 3 - 100%) for night use, and on three for day use. These analyses, then, include only a small fraction of all the data obtained. For that reason, the findings must be considered as tentative, and not as reliable as they would be if more data were included.

Criteria of Seeing: All observers were able to set up, and adhere to, a uniform criterion for reporting "first glimpse" and "100% frequency of seeing" of the targets. Considerable variation appeared among observers in criteria for reporting "positive identification" of targets. This criterion, however, proved to remain relatively constant for a given observer.

Observation Position: A substantial difference was found between ranges obtained on the signal bridge, and on the gun deck, at night. This did not appear in the day runs. No marked differences in ranges or variability were found among data obtained at each of the six positions on the signal bridge, or of the three positions on the gun deck, at night.

Visibility: Highly reliable statistical differences were found among the performances obtained on different dates. These may be directly related to visibility differences. It is anticipated that further analysis, based upon more complete data, and employing the Tiffany data, may yield values

of data, the coefficient of atmospheric extinction for each night, and consequently make possible a more meticulous comparison of the instruments.

Wind: The data indicate that high winds yield greater variability of performance, without decrease of mean ranges.

Individual Differences: Analysis of the data to date show conclusively that consistent individual differences among observers exist. Four groups may be distinguished. These are: (a) consistently good, (b) consistently poor, (c) "average", and (d) highly variable observers. The good observers seem to show absence of phoria, as measured by the Orthorater, and the poor ones have a large proportion of RPA scores below 10/10. No other tests have yet proven diagnostic of performance. These results, however, are tentative only, since the data on many of the observers are few in number.

DISCUSSION:

Comdr. Volk asked whether the New London studies indicated that a change in the present Navy binocular procurement should be made.

Lt. Verplanck replied that the New London studies indicated clearly that 10x50 binoculars were superior to 7x50. However, in search, there is not as great an improvement with the additional power as in ordinary viewing.

Professor Hecht expressed the belief that the New London studies indicated relatively small differences between the various instruments tested. He believed that a radically new approach to binocular design was needed so that radically greater improvements in performance could be obtained.

Dr. Brackett asked what the visual task involved in the New London studies was. He expressed the belief that in the New London study, since form recognition was not tested, more discouraging results were obtained than would result in general. He reported that experiments conducted at Ft. Knox while he was with the Army, indicated encouraging results with high power binoculars at night when recognition was desired.

Dr. Miller reported that toward the end of the Brown program, targets were used which involved form discrimination. He expressed the belief that far greater improvement was obtained with binoculars than had been obtained in the earlier experiments.

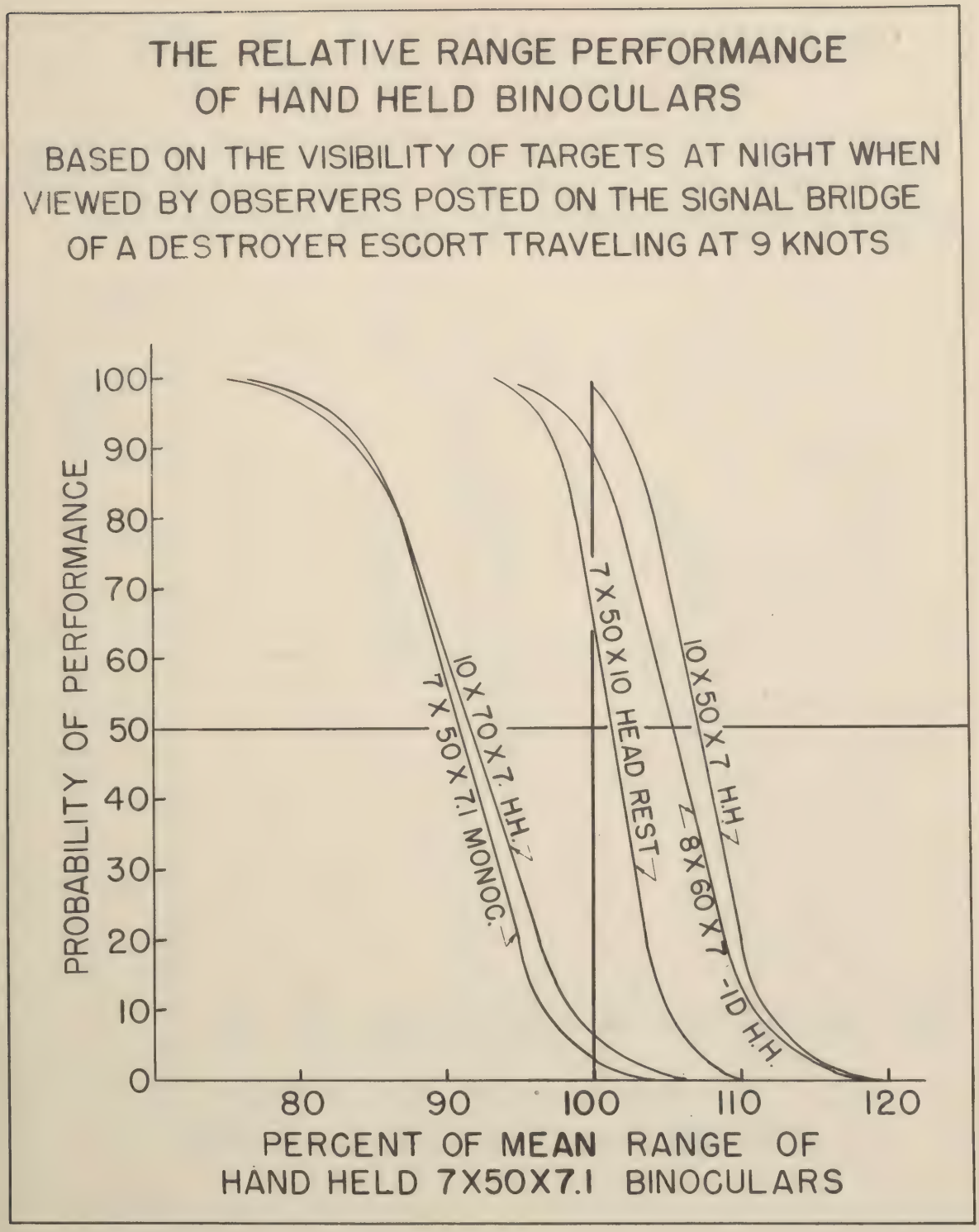

THE RELATIVE RANGE PERFORMANCE
OF HAND HELD BINOCULARS
BASED ON THE VISIBILITY OF TARGETS AT NIGHT WHEN
VIEWED BY OBSERVERS POSTED ON THE SIGNAL BRIDGE
OF A DESTROYER ESCORT TRAVELING AT 9 KNOTS
PROBABILITY OF PERFORMANCE
100
90
80
70
60
50
40
30
20
10
0
80
90
100
110
120
PERCENT OF MEAN RANGE OF
HAND HELD 7X50X7.1 BINOCULARS
10 X 70 X 7. H.H.
7 X 50 X 7.1 MONOC.
7 X 50 X 10 HEAD REST
10 X 50 X 7 H.H.
8 X 60 X 7 -1D H.H.

FIGURE 1A

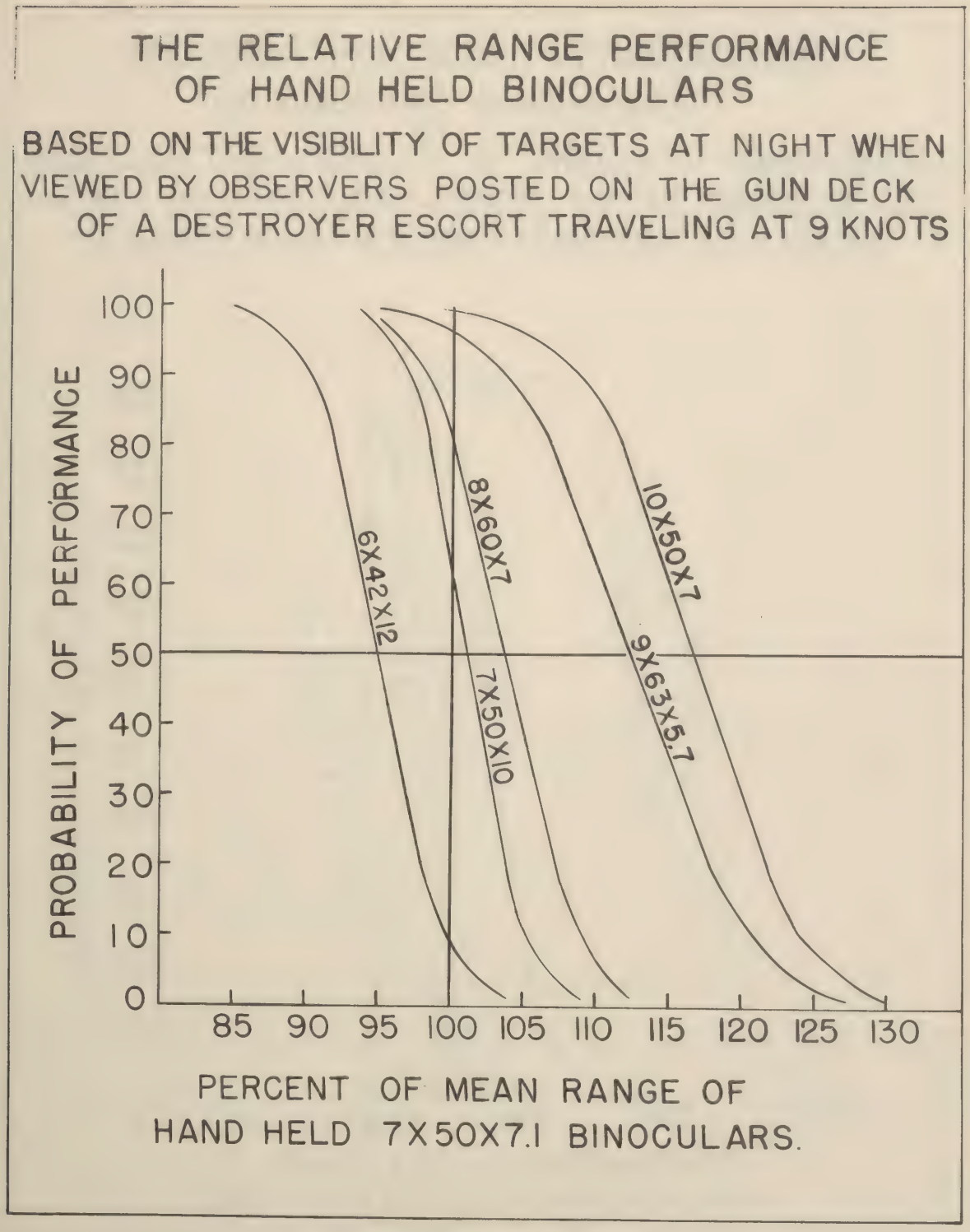

THE RELATIVE RANGE PERFORMANCE
OF HAND HELD BINOCULARS
BASED ON THE VISIBILITY OF TARGETS AT NIGHT WHEN
VIEWED BY OBSERVERS POSTED ON THE GUN DECK
OF A DESTROYER ESCORT TRAVELING AT 9 KNOTS
PROBABILITY OF PERFORMANCE
100
90
80
70
60
50
40
30
20
10
0
6X42X12
8X60X7
7X50X10
9X63X5.7
10X50X7
85
90
95
100
105
110
115
120
125
130
PERCENT OF MEAN RANGE OF
HAND HELD 7X50X7.1 BINOCULARS.

FIGURE 1B

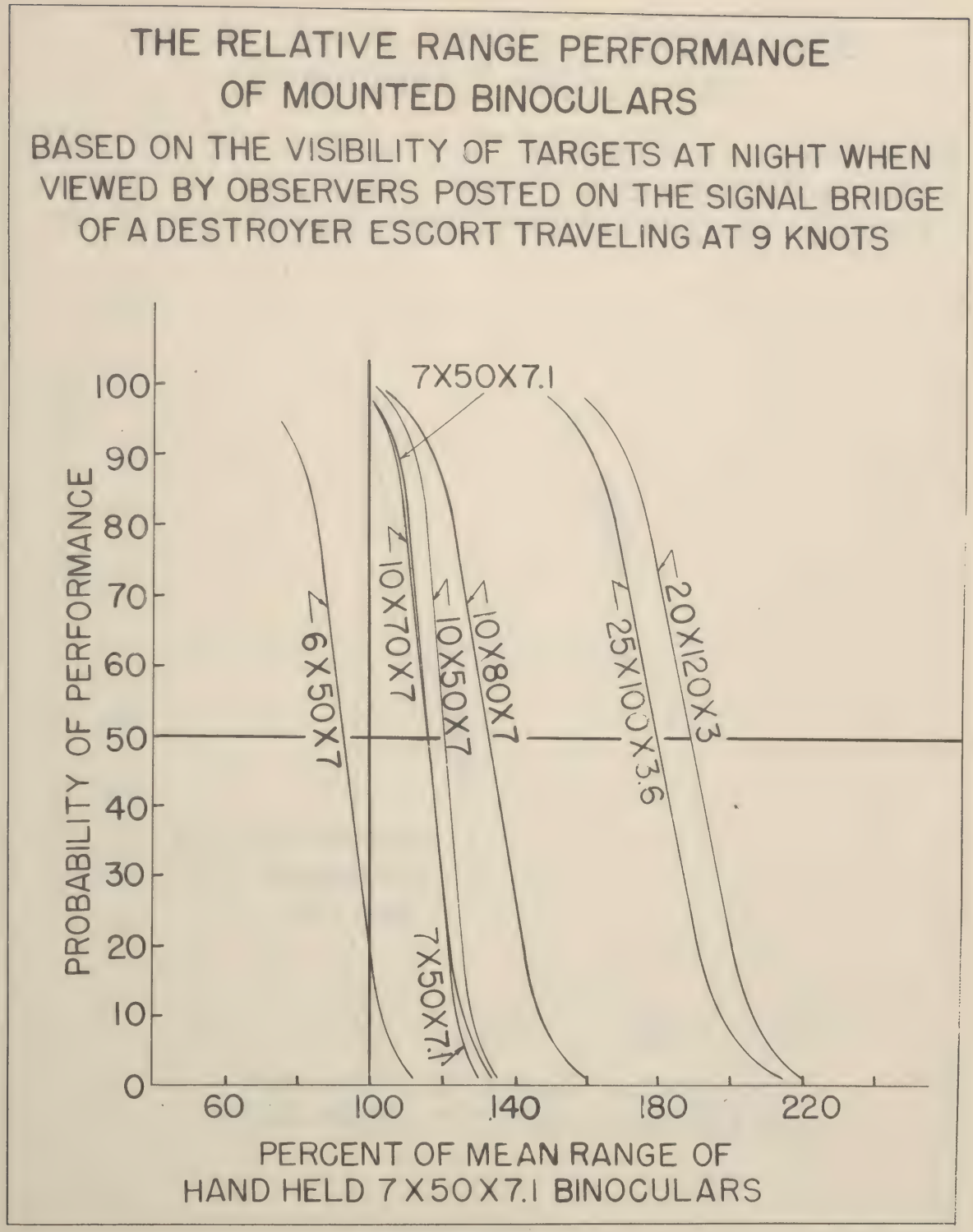

THE RELATIVE RANGE PERFORMANCE
OF MOUNTED BINOCULARS
BASED ON THE VISIBILITY OF TARGETS AT NIGHT WHEN
VIEWED BY OBSERVERS POSTED ON THE SIGNAL BRIDGE
OF A DESTROYER ESCORT TRAVELING AT 9 KNOTS
PROBABILITY OF PERFORMANCE
100
90
80
70
60
50
40
30
20
10
0
7X50X7.1
6X50X7
10X70X7
10X50X7
10X80X7
25X100X3.6
20X120X3
7X50X7
60
100
140
180
220
PERCENT OF MEAN RANGE OF
HAND HELD 7X50X7.1 BINOCULARS

FIGURE 2A

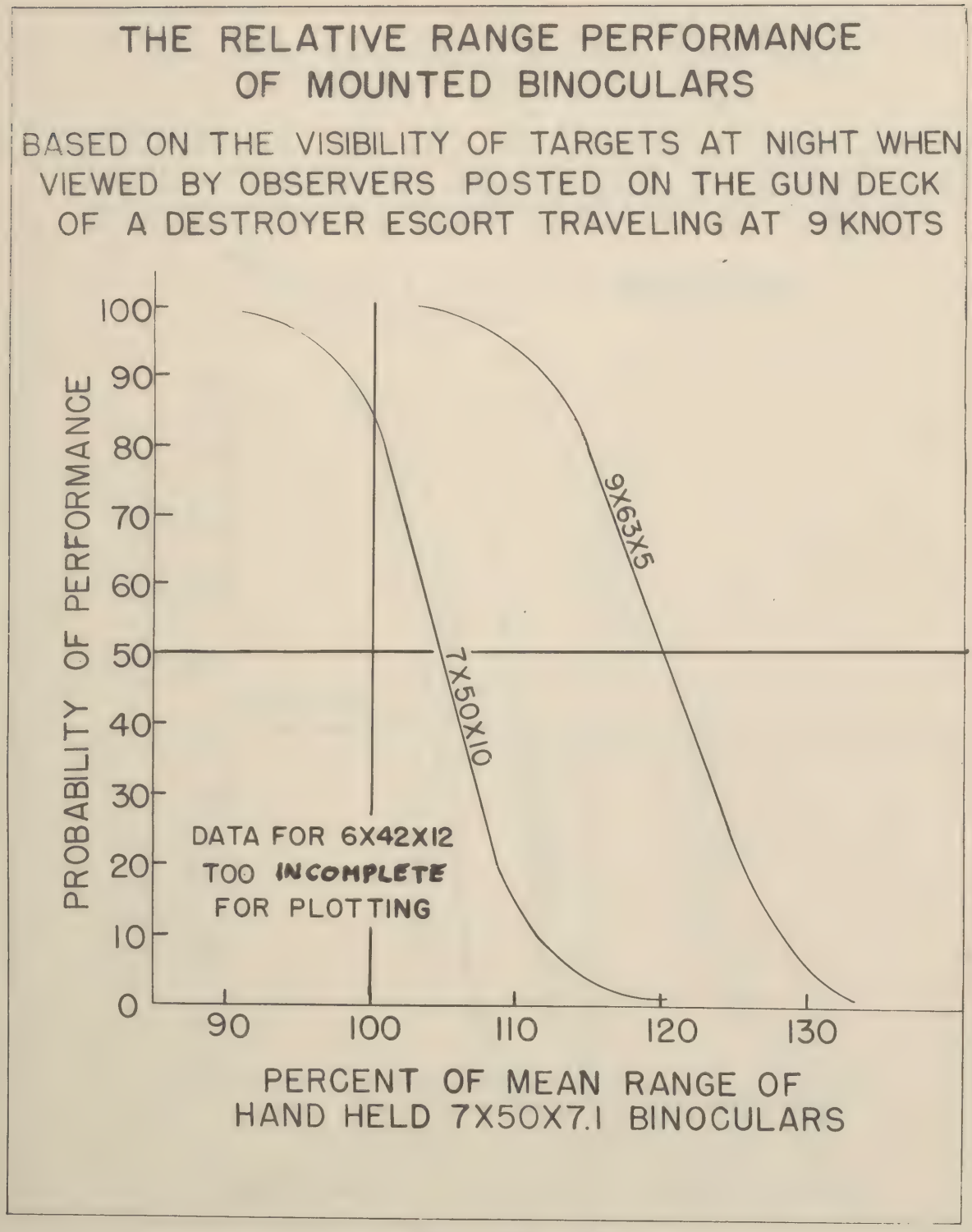

THE RELATIVE RANGE PERFORMANCE
OF MOUNTED BINOCULARS
BASED ON THE VISIBILITY OF TARGETS AT NIGHT WHEN
VIEWED BY OBSERVERS POSTED ON THE GUN DECK
OF A DESTROYER ESCORT TRAVELING AT 9 KNOTS
PROBABILITY OF PERFORMANCE
100
90
80
70
60
50
40
30
20
10
0
9X63X5
7X50X10
DATA FOR 6X42X12
TOO INCOMPLETE
FOR PLOTTING
90
100
110
120
130
PERCENT OF MEAN RANGE OF
HAND HELD 7X50X7.1 BINOCULARS

FIGURE 2B

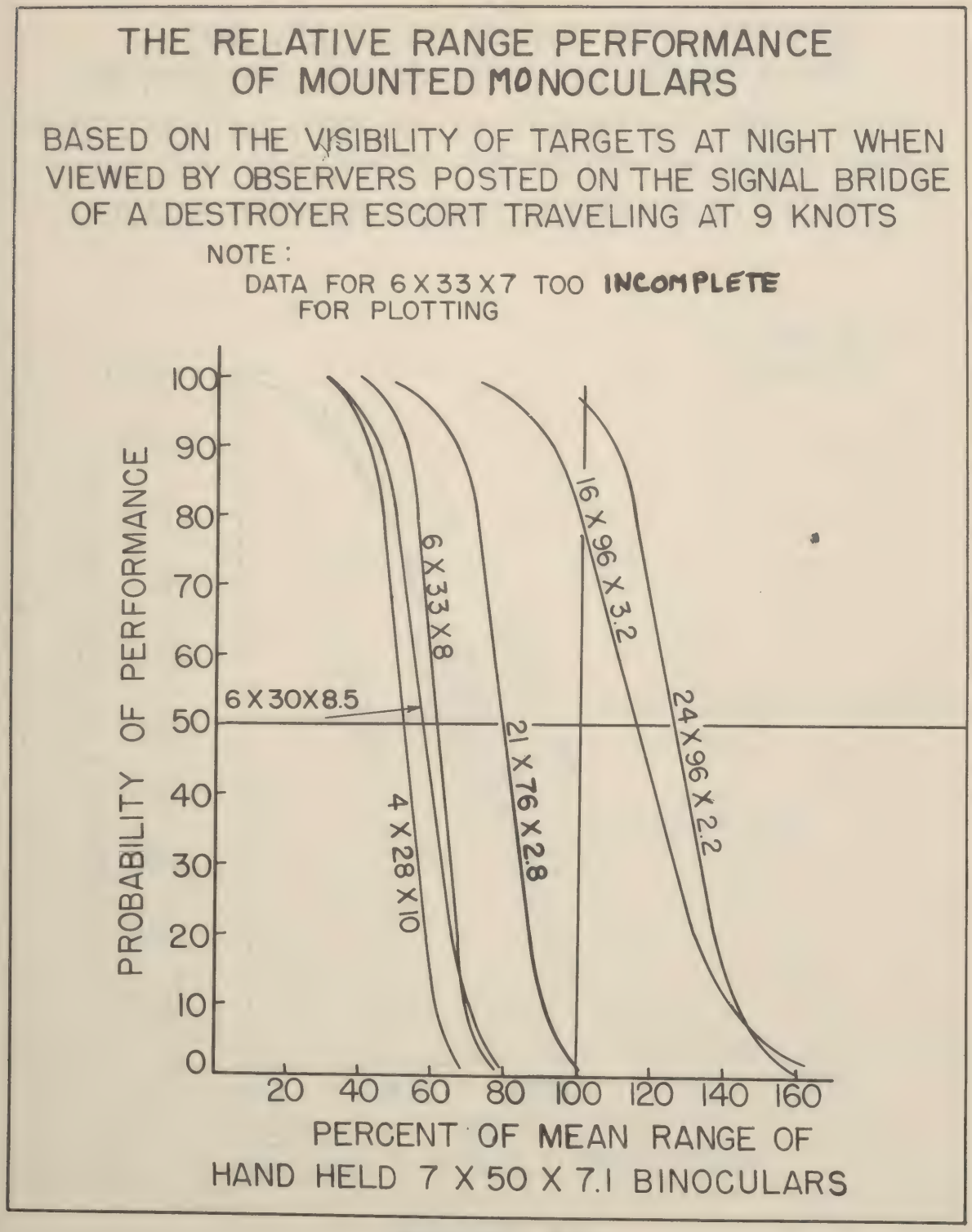

THE RELATIVE RANGE PERFORMANCE
OF MOUNTED MONOCULARS
BASED ON THE VISIBILITY OF TARGETS AT NIGHT WHEN VIEWED BY OBSERVERS POSTED ON THE SIGNAL BRIDGE OF A DESTROYER ESCORT TRAVELING AT 9 KNOTS
NOTE:
DATA FOR 6 X 33 X 7 TOO INCOMPLETE FOR PLOTTING
PROBABILITY OF PERFORMANCE
100
90
80
70
60
50
40
30
20
10
0
6 X 30 X 8.5
4 X 28 X 10
6 X 33 X 8
21 X 76 X 2.8
16 X 96 X 3.2
24 X 96 X 2.2
20
40
60
80
100
120
140
160
PERCENT OF MEAN RANGE OF
HAND HELD 7 X 50 X 7.1 BINOCULARS

FIGURE 3

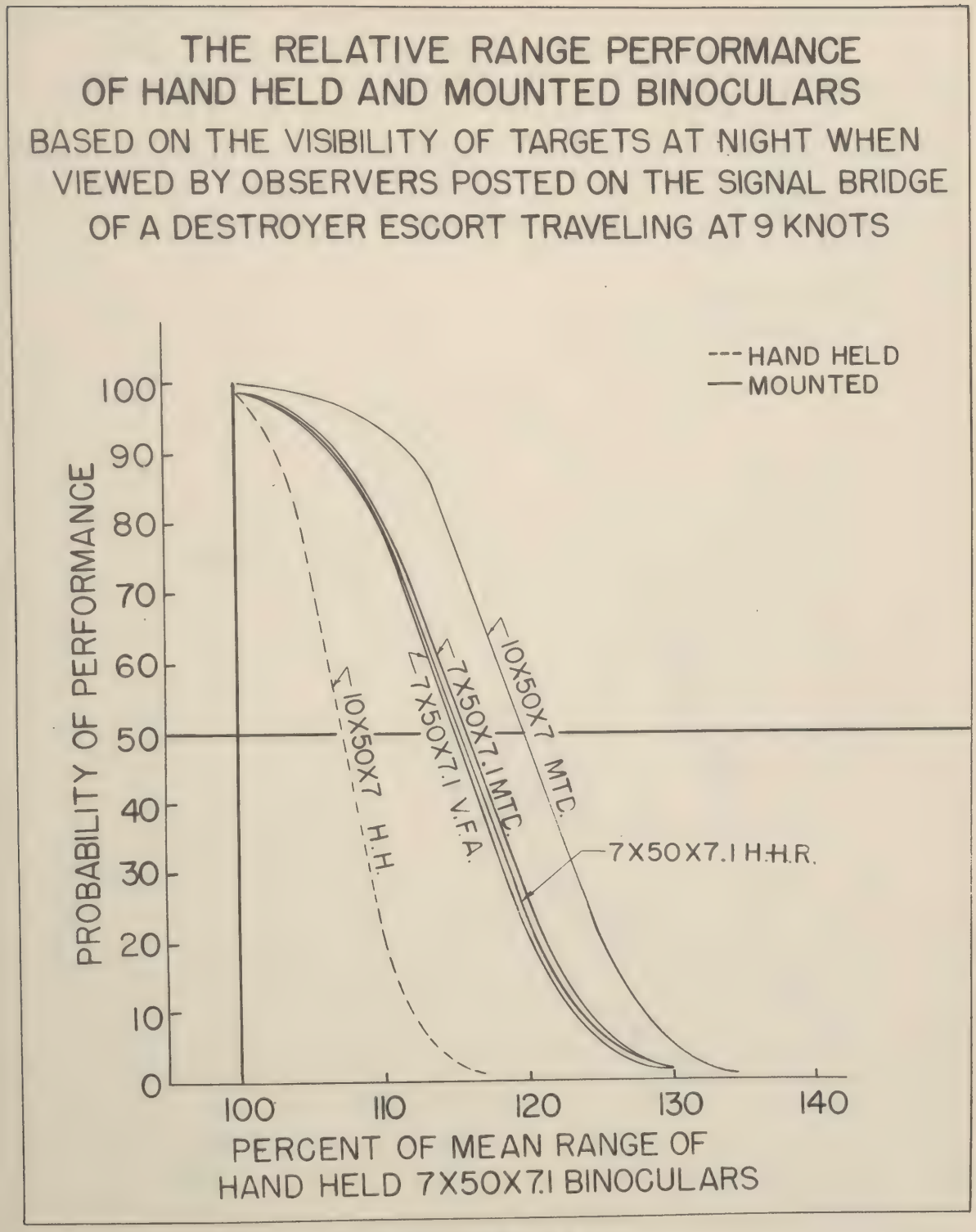

THE RELATIVE RANGE PERFORMANCE
OF HAND HELD AND MOUNTED BINOCULARS
BASED ON THE VISIBILITY OF TARGETS AT NIGHT WHEN
VIEWED BY OBSERVERS POSTED ON THE SIGNAL BRIDGE
OF A DESTROYER ESCORT TRAVELING AT 9 KNOTS
--- HAND HELD
— MOUNTED
PROBABILITY OF PERFORMANCE
100
90
80
70
60
50
40
30
20
10
0
10X50X7 MTD.
7X50X7.1 MTD.
7X50X7.1 V.F.A.
10X50X7 H.H.
7X50X7.1 H.H.R.
100
110
120
130
140
PERCENT OF MEAN RANGE OF
HAND HELD 7X50X7.1 BINOCULARS

FIGURE 4A

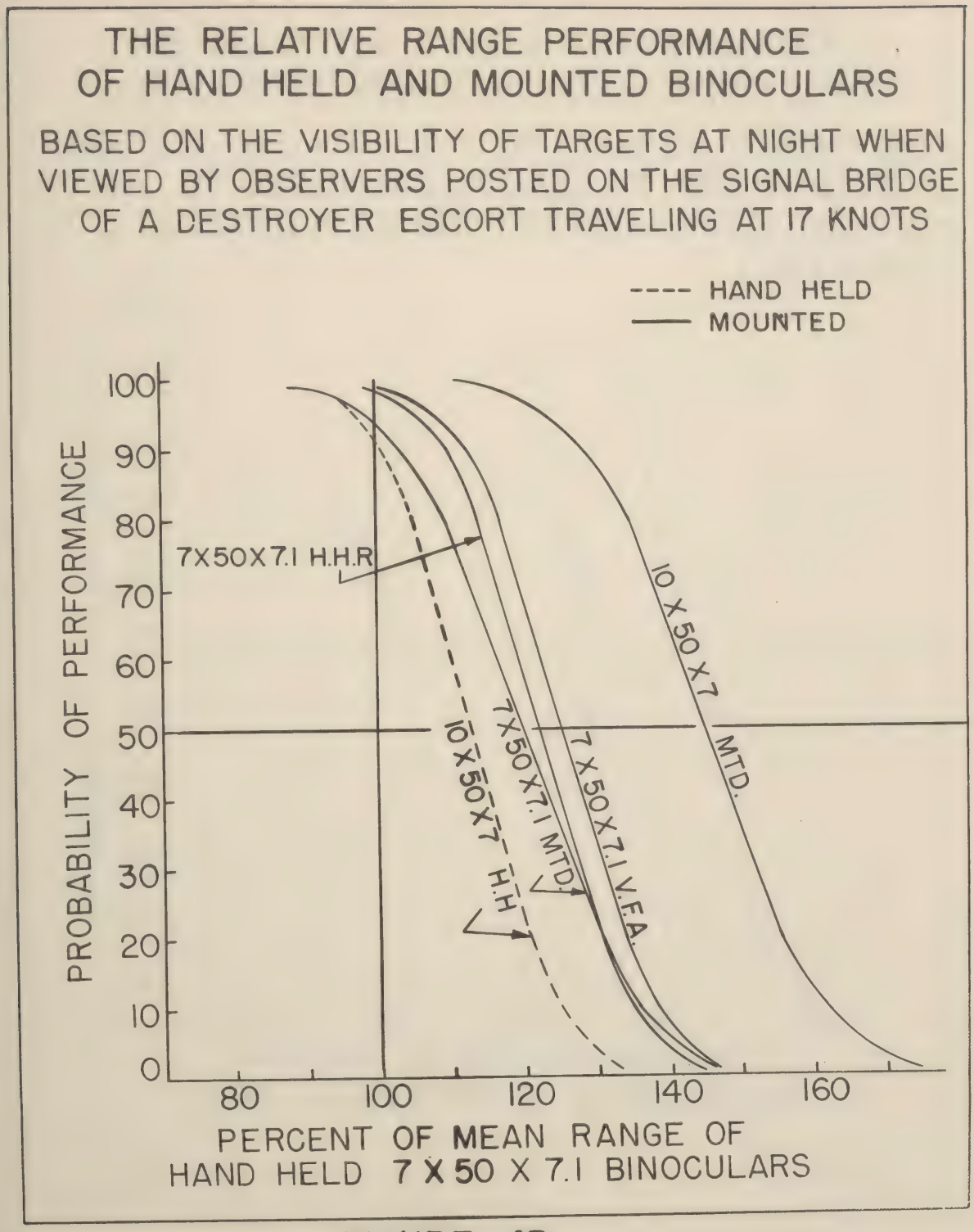

THE RELATIVE RANGE PERFORMANCE
OF HAND HELD AND MOUNTED BINOCULARS
BASED ON THE VISIBILITY OF TARGETS AT NIGHT WHEN
VIEWED BY OBSERVERS POSTED ON THE SIGNAL BRIDGE
OF A DESTROYER ESCORT TRAVELING AT 17 KNOTS
---- HAND HELD
—— MOUNTED
PROBABILITY OF PERFORMANCE
100
90
80
70
60
50
40
30
20
10
0
7X50X7.1 H.H.R
10 X 50 X 7 MTD.
7 X 50 X 7.1 MTD.
7 X 50 X 7.1 V.F.A.
10 X 50 X 7 H.H
80
100
120
140
160
PERCENT OF MEAN RANGE OF
HAND HELD 7 X 50 X 7.1 BINOCULARS

FIGURE 4B

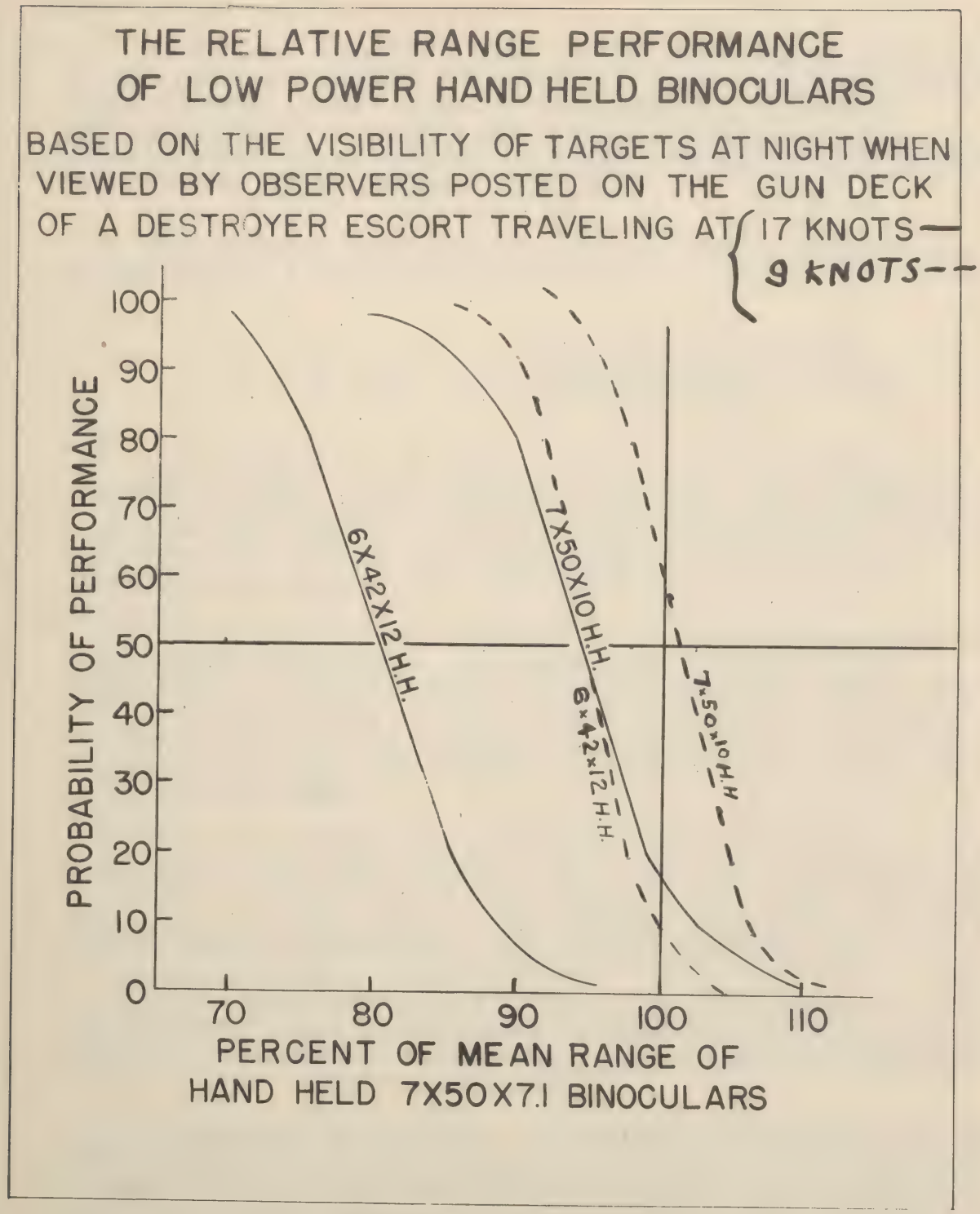

THE RELATIVE RANGE PERFORMANCE
OF LOW POWER HAND HELD BINOCULARS
BASED ON THE VISIBILITY OF TARGETS AT NIGHT WHEN
VIEWED BY OBSERVERS POSTED ON THE GUN DECK
OF A DESTROYER ESCORT TRAVELING AT 17 KNOTS
9 KNOTS
PROBABILITY OF PERFORMANCE
100
90
80
70
60
50
40
30
20
10
0
6X42X12 H.H.
7X50X10 H.H.
6×42×12 H.H.
7×50×10 H.H.
70
80
90
100
110
PERCENT OF MEAN RANGE OF
HAND HELD 7X50X7.1 BINOCULARS

FIGURE 5

[redacted]

THE CONTRAST RENDITION OF OPTICAL INSTRUMENTS

Dr. Howard S. Coleman
The Pennsylvania State College

An optical quantity, referred to as "Contrast Rendition" of optical instruments, is being studied at The Pennsylvania State College, under terms of Navy Contract NOrd-7958. This quantity is a measure of how nearly an image of an object formed by an optical instrument resembles the object with respect to brightness contrast.

The Contrast Rendition (C.R.) of an optical instrument is defined by the following equation:

$$C.R. = \frac{C_i}{C_o} \times 100$$

Where C_i equals image contrast, and C_o equals object contrast.

The contrast of an image of an optical instrument is reduced by stray light scattered over it. All instruments have a certain amount of stray light resulting from reflection from the optical and mechanical parts, and hence a Contrast Rendition of less than 100%.

The range at which targets are visible depends upon the contrast of the target. Any reduction in the apparent contrast of a target requires that the observer reduce the distance between him and the target to render it visible. If, therefore, Contrast Rendition of an optical instrument is less than 100%, the target could not be seen as far away as if it were 100%.

It is of interest to determine the influence of Contrast Rendition on the effectiveness of an optical instrument, and to compare its importance with other factors known to control the range at which targets are visible, such as the magnification, light transmission, and optical aberrations.

In the statements that follow, the characteristics of the observer's eye do not appear explicitly, as the conclusions are intended to refer only to the characteristics of the visual aid under consideration.

Preliminary measurements of Contrast Rendition have been made under different conditions of the optical instruments, illumination, target size, target contrast, light transmission, and field angles. These measurements have been considered in terms of the loss of range caused by imperfect Contrast Rendition for eighteen different binoculars (36 single telescopic systems), and imply the following:

[redacted]

1. The Contrast Rendition of a given design of 7x50 binoculars is substantially identical.

2. The Contrast Rendition is less perfect for 7x50 binoculars coated with magnesium fluoride, under most conditions of illumination, than non-coated instruments.

3. The loss in range caused by imperfect Contrast Rendition (90%) for carefully cleaned 7x50 binoculars may be as much as 25% under conditions of illumination in which the target brightness is 0.1 of that of the background.

4. The loss in range caused by imperfect Contrast Rendition of 7x50 binoculars occurs for targets of any pratical size.

5. The Contrast Rendition is independent of the target contrast for 7x50 binoculars.

6. A single thumb print on the outside surface of an objective of a coated 7x50 binocular may cause as much as 10% loss in range, for high-contrast targets, and 50% or more for low-contrast targets. These losses mentioned refer to uniform illumination conditions of the background of the target.

7. The Contrast Rendition of sixteen carefully cleaned Mark 32 binoculars was found to be 90% on the average.

8. The Contrast Rendition and light transmission of Mark 32 binoculars are constant for total field angles of at least 4°.

9. From a general point of view, Contrast Rendition in optical instruments appears to be at least as important as light transmission, and magnification (assuming the exit pupil to be the same in each case, and larger than the maximum pupil of the eye.

10. The Contrast Rendition for Mark 32 binoculars does not depend upon the optical quality. The axial K.D.C. efficiencies for sixteen Mark 32 binoculars ranged from 44% to 92%, and from 10% to 92% for a true field of up to 4°, while the Contrast Rendition did not vary by more than a few percent from 90% under the same conditions.

The loss in range caused by imperfect Contrast Rendition, light transmission, and magnification in 7x50 binoculars has been analyzed on the basis of data reported under terms of OSRD Contract OEMsr-597. These data were collected at the Louis Comfort Tiffany Foundation at Oyster Bay, Long Island. This analysis indicates that it is convenient to consider the visibility of targets for three general levels of illumination. These are: daylight (over 10^{0} footlamberts), twilight (10^{-1} footlamberts), and starlight (10^{-4} footlamberts).

The sensitivity to reduction in range caused by imperfect Contrast Rendition, magnification, and light transmission, under the three levels of illumination, is under consideration. The preliminary study implies that losses in range caused by imperfect Contrast Rendition occur at all brightness levels, and that this is not the case for the magnification and light transmission of the visual aid under consideration. These implications are of considerable importance from a military point of view, and, therefore, should be reviewed carefully.

An analysis has been made to ascertain whether the New London binocular test results can be explained on the basis of the contrast rendition and light transmission of the instruments. Measurements on all the instruments used in the New London study were made of contrast rendition, light transmission, and magnification. The relative efficiencies of the several instruments were computed from these measurements, together with the Tiffany visibility data. These efficiencies express the amount by which the range of target will be increased under standard New London atmospheric conditions. It was found that almost without exception such an analysis was sufficient to predict with precision the performance actually obtained in field test at New London. In order to rationalize the fact that the New London results are predictable on the basis of measurements of optical quality in conjunction with visibility data, it must be assumed that such influences as misalignment and tremor are constant for all instruments. It is believed that the gratifying similarity between results obtained at New London and those computed makes possible the prediction of performance of instruments without the necessity for field tests.

DISCUSSION:

Lt. Comdr. Pulling summarized ways in which the Vision Committee had served the Bureau of Ordnance during the war years and emphasized the need for further research and coordination of knowledge of optical instruments.

Dr. Hartline asked Dr. Coleman how accurate his predictions would have been if he had omitted the influence of contrast rendition.

Dr. Coleman replied that at least one-third of the reduction in effectiveness of the binoculars was caused by contrast rendition. Without this factor, the prediction would have been much less satisfactory.

Dr. Miller emphasized that the contrast rendition factor did not enter into the Brown or Dartmouth studies because of the small angle surround used.

Dr. Brackett emphasized the necessity for sunshades in order to reduce the large amounts of contrast rendition which Dr. Coleman has shown to be important to the effectiveness of binoculars.

Dr. Neuberger cautioned the group against accepting the Tiffany nomographs as entirely valid because of the inadequacy of the law of atmospheric scattering under certain circumstances. He emphasized that Koshmeiders formula is valid only for exceptional atmospheric conditions in which clear sky or uniformly cloudy sky is present.

Dr. Hartline emphasized that the various reports which had been discussed contained together sufficient information for good prediction of the effectiveness of binoculars. He emphasized the need for coordination of the available information into a form which would make it readily useful to the services.

Capt. Shilling concurred in Dr. Hartline's opinion and asked the Subcommittee on Binoculars to meet and return to the Committee a recommendation concerning a mechanism for coordinating the knowledge on binoculars.

[redacted]

CORRECTION OF REFRACTIVE ERRORS BY TRAINING

Dr. Frederick K. Reid

(This material is not classified)

In connection with routine testing at the United States Military Academy, West Point, studies have been made of the extent to which low degrees of myopia can be improved. Results are reported for 35 patients. Of this group, 20 had been placed under a definite regime of exercise during their college schedule to improve vision; the remaining 15 were examined at various times during a normal college schedule which did not include special exercises.

It was found that a definite increase in improvement resulted in 17 of the 20 patients subjected to exercise. The amount of improvement varied from subject to subject: From the control group it was learned that improvement was often the result of rest alone. In the cases where improvement in visual acuity was obtained, the refractive error under cycloplegia was not altered. The improvement obtained was complete after a period of from two to six weeks of exercise. It was the belief of the experimenters that the improvement of visual acuity was accomplished by training the patients to relax their accommodation. A portion of the original diminution of acuity was thought to be the result of accommodation spasms. The patients who showed improvement in acuity had originally less than normal accommodative range.

It was found that the improvement in acuity was eliminated when the patients underwent sustained near work, in spite of continued exercise.

DISCUSSION:

Lt. Comdr. Farnsworth asked Dr. Reid what test objects had been used for testing visual acuity.

Dr. Reid reported that the regulation Snellen Chart and the Landolt C tests were used. An attempt was made to standardize the illumination on the charts. Dr. Reid reported that they found 20 to 25% less improvement in visual acuity as tested by the Landolt C method.

Dr. Tousey asked whether there were changes in astigmatism from day to day.

Dr. Reid reported that small changes of axis amounting to 5 to 10% were found.

[redacted]

Lt. Comdr. Imus asked whether it might not prove desirable to give the patients who entered the exercise program used base-in prisms for close work.

Dr. Reid replied that they had never attempted such a program except that patients who entered the exercise program used base-in prisms for this purpose.

Dr. Beck asked how the improvements of acuity varied for different kinds of original refraction.

Dr. Reid answered that the studies undertaken at West Point had not shown whether hyperopia could be similarly diminished by exercise. Dr. Reid took the occasion to remark that there was still a need for standardization of visual examinations for entrance into the Army, particularly for commissioned personnel.

Dr. Wald, referring to the conclusion that Dr. Reid has reached that relaxation of accommodation was responsible for improvement in acuity suggested the possibility that it was not the close work but rather the strain and tension of academic work which produced the reduction in acuity.

Dr. Burger emphasized that the study was concerned solely with a limited age group. He emphasized that the progress of myopia differs with age and that the conclusions reached in the Reid study might not be valid for other age groups.

Dr. Sulzman remarked that it is not safe to conclude that myopia results only from close work in that there is an equally high incidence of myopia among normals and illiterates. He referred to the conclusion of Bacon that visual acuity is related to thyroid activity.

Mr. Blackwell remarked that the smaller degree of improvement with the Landolt C chart indicated the possibility that no improvement would be obtained with a chart measuring sheer retinal resolution.

Lt. Comdr. Farnsworth expressed the belief that the Landolt C test went a long way toward testing retinal resolution, at least compared to the Snellen charts. He suggested that at the conclusion of the AGO visual acuity research it might prove desirable to recommend the use of a new type of chart for any future tests of this sort.

THE EFFECT OF SPECTACLE LENS POWER ON POINT SOURCE AND VISUAL ACUITY THRESHOLDS

Dr. Richard Tousey

Naval Research Laboratory

(This material is not classified)

Experimental work indicated that many individuals of normal daytime vision will gain very significantly in ability to see at night if they wear at night negative spectacles of the proper power. The gains may be as great as three times in range in certain cases. The cause for this is that the eye becomes nearsighted at night. The optimal focussing of binoculars at night is discussed and the possible causes for "nocturnal myopia" are considered.

INTRODUCTION

During the last few years it has been independently observed by several persons that somewhat better vision at night often resulted from the use of spectacles one, or even two diopters more negative than the observer's normal daytime correction. A similar effect has been observed with binoculars, which most persons tend to focus a diopter or two more negative at night than by day. This means that the normal sighted eye becomes nearsighted at night. I should like to propose that this effect be called "Nocturnal Myopia."

This was noticed at NRL in 1943 and commented on in a report on gunsight reticles. It turned out that the French and the Spanish also knew about it. The British made extensive qualitative investigations of it and published a very good report covering most of the causes. The Vision Committee has talked about it on various occasions and yesterday Dr. Wald reported to the Subcommittee on Binoculars on his investigation of this effect in binoculars. As a further check on the existence of the effect, Lt. Comdr. Nolan and I at the Vision Committee meeting at Fort Knox, passed around to the group during the outdoor nighttime demonstration my minus one slip over spectacles, which I always carry with me as a nighttime visual aid. We received favorable comments on their effectiveness from 14 out of 18 persons and no one said that they impaired vision.

I have been quite interested in nocturnal myopia and have carried on experimentation at irregular intervals over a period of several years in an attempt to assess the importance of the effect and to run down the causes. The work is still very far from complete, but I would like to present the data which we now have at this time.

Methods of Experimentation

At NRL Lt. H. A. Knoll, Mr. M. Koomen, Mr. W. Allen and I have attempted, first, to measure the effect on various visual thresholds of spectacle lenses of different powers and second, to devise very special experiments in an attempt to determine exactly what causes the negative shift. The thresholds measured so far were of two types; point source thresholds for a wide range of background brightnesses, and acuity thresholds using high contrast barred targets on a uniform white surround.

The point source threshold equipment consisted of a small hole placed over the opal glass of a Macbeth Illuminometer the head of which was removed and collimated by means of an Aero-Ektar 24-inch focal length f/3 lens. The observer looked into the lens and saw the point source as at infinity. The background was reflected in by introducing a plate of glass at 45 degrees between the lens and the observer. Source and background were white, of color temperature 2360° K.

The acuity measurements were made in a tunnel with target 20 feet from the observer and illuminated uniformly by means of a projector with white light of 2850° K color temperature. The barred target subtended 4 degrees at the observer and the surround in both experiments subtended 14 degrees at the observer.

In order to vary the spectacle power conveniently all observations were made through a phoropter. This permitted the power to be changed by the observer in steps of 0.25 diopter. Observers who normally wore spectacles removed them, and any astigmatism present was corrected for by introducing the proper corrective lens in the phoropter. Only the spherical correction was varied during the experiments.

Results

Figure 1 shows the results of the point source work for three observers, a myope, an emmetrope and a hyperope. Curves are given for each observer for a completely dark background and for several bright backgrounds. It can be seen that the lowest thresholds occurred for powers between one and two diopters negative relative to the best correction for daytime. For the myope, whose best vision in daytime was with -4.75 diopters, best night vision occurred with -6.5, a shift of -1.75 diopters. For the emmetrope shown and several other emmetropes, best night vision was for -1.5 diopters. The hyerope seemed to tolerate approximately +2 diopters for daytime without loss of acuity and his best night vision on point sources was for zero correction, again a shift of about -2 diopters.

At the brighter backgrounds the curves show much sharper minima than for dark backgrounds. This is reasonable, since for complete darkness the acuity of the eye is very low, and a slightly out of focus patch is about as effective as a sharp image. For brighter backgrounds, the effect of poor focus is to produce a disk image of low contrast relative to the background and much harder to see than if all the light were concentrated in a sharp image. It would be interesting to calculate curves of this sort from the Tiffany data and the optics of the eye and see if a simple explanation of this sort is valid.

The acuity targets were somewhat easier to work with than the point source, and Figure 2 shows the results for the two observers we have measured so far. The data are much more accurate than for the point source. It can be seen that here again there was a shift of optimal correction from high to low levels of approximately -2 diopters. There was very little shift down to about 10 uL, where rod vision began to take over, and then a rather rapid shift. The shifts for the myope and emmetrope were approximately the same. Their maximum acuities at corresponding brightnesses did not agree exactly, but this was not surprising. One reason probably was that their pupil curves were not alike.

Figure 3 shows the diopter shift for the acuity thresholds plotted against surround brightness. This shows a rather definite bend below 10 uL, which was near the rod cone break, with very little shift in correction above this level. The two observers did not agree perfectly and we believe that the disagreement was real and was more than the experimental error.

The possibility that accommodation influenced these results, as Dr. Wald has shown in his work on binoculars, has given us some worry. We have not yet paralyzed the accommodative muscles and perhaps should do this. However, all the observers were experienced and especially so those used with the acuity targets. They were able to accommodate through conscious effort and also knew how to prevent accommodation. They were aided by the use of binocular vision. We have had only a few instances where accommodation was suspected.

Increase in Nighttime Visual Ranges

We now come to the important question--How much farther can an observer see at night if he wears spectacles of optimium power? Figure 4 shows the conclusions we have reached from the data shown on the previous slides. The results are definitely preliminary, but all point to large possible gains. Taking first the grating targets, we see that the use of the best spectacle corrections for each level,

instead of that which gave best daytime vision, resulted in no gain to speak of at photopic levels, but in great gains, from 50 to 75% in range, at scotopic levels. For point sources the data were conflicting but the curve was very approximately as shown and in any case was very different in shape from the curve for acuity thresholds. For the point source the gain was only 15% in complete darkness, but was much higher at twilight.

It was concluded from these results that the three classes of individuals, emmetropes, myopes and hyperopes, actually will secure rather different gains by the use of the best corrective spectacles at night. First, consider hyperopes of at least 1 diopter. They have excellent vision but have to accommodate during daytime, unless they wear corrective spectacles. At night they correct for nocturnal myopia simply by relaxing accommodation. Therefore, their vision at night will be excellent and on the average better than that of emmetropes. Emmetropes become nearsighted by one or 2 diopters at night but have no means of correcting for this. By use of proper spectacles they will gain 50 to 75 per cent in visual ranges under certain conditions. Myopes stand to gain most of all. Consider first those persons with a small degree of uncorrected myopia, 1/2 or 3/4 diopter. In the Services I understand that it is general practice not to prescribe corrective spectacles for this amount. These individuals become very nearsighted at night. The curves of Figure 2 show that they should obtain very great increases in nighttime visual ranges. If they wear the proper spectacles for nighttime use, they should see objects two or even three times as far away under certain conditions. The second class of myope wears spectacles but usually somewhat less than full correction for daytime. The myope who made the measurements shown on Figure 2 was of this type. His best daytime correction was -4.75, while his prescribed spectacles were -4.12. The curves show that at night when wearing the best spectacles he obtained on acuity targets threshold ranges nearly three times greater than when wearing his prescribed spectacles.

In summary, then, hyperopes will gain little or nothing from the use of the best corrective spectacles at night, emmetropes up to 75 per cent in range and myopes up to three times in range.

These conclusions are based on measurements with very few individuals and obviously the work must be carried much further. We are continuing with the work. We intend also to try the experiment out-of-doors at night. Our experiments so far have been restricted to surrounds not larger than 15 degrees. One of the next things we intend to do is to use 180 degree surrounds.

Effect on Binoculars

These results have a direct bearing on the optimal focus of binoculars for nighttime use, which was discussed by Dr. Wald yesterday. The case of binoculars is complicated, however, by other factors, such as the chromatic aberration and field curvature of the binocular, the effective exit pupil, vibration, etc. However, the shift for the naked eye appears to be of the same magnitude as has been observed with binoculars.

The results also bear directly on the applicability of the Tiffany data to calculations of visibility through binoculars. It would be expected that the observed gain at night by the use of binoculars, would be greater than the gain as calculated from the Tiffany data because the binoculars permit throwing in the optimum correction for the observer's nocturnal myopia and in the Tiffany experiments, the naked eye without optimal correction was used. This seems to increase the gap which was brought out so clearly yesterday between actual and expected binocular performance.

Causes For Nocturnal Myopia

We come now to the possible causes for nocturnal myopia. The following discussion covers most of the factors. We still do not know definitely, which ones are responsible, however.

1. Longitudinal Chromatic Aberration together with the Purkinje Effect causes nocturnal myopia to the extent of -0.3 or -0.4 diopter. Lateral Chromatic Aberration may have a similar effect.

2. Macular pigmentation together with Chromatic Aberration may cause nocturnal myopia because at high levels vision is foveal and the pigmentation interposes a yellow filter, whereas at low levels vision may be extra-macular and here the filter is absent.

3. The yellow lens pigmentation taken together with Chromatic Aberration and the Stiles-Crawford Effect may cause nocturnal myopia. At high levels, due to the constricted pupil and also the Stiles-Crawford Effect, most of the light enters in effect through the center of the lens which is the thickest part and therefore the most dense yellow filter. At low levels the pupil is dilated and there is no Stiles-Crawford Effect and most of the effective light enters the eye through the outer zones of the lens. Here the lens is thinnest and the filtering action least.

4. Spherical Aberration together with the Stiles-Crawford Effect is responsible, we believe, for a considerable degree

of nocturnal myopia. At high levels the center of the lens is used principally, due to pupil constriction and also the Stiles-Crawford Effect. At low levels, since the pupil is dilated and the Stiles-Crawford Effect does not apply, the outer zones come into use and have a very great effect, since their areas are proportional to their diameters. The outer zones are myopic by at least a diopter and hence the eye as a whole will be myopic when the outer zones are contributing to vision.

5. The resolving characteristics of the eye may tend to accentuate the spherical aberration effect. At low photopic levels, vision through the central pupil is very acute and is more acute than vision through marginal zones even if properly corrected for their spherical aberration. This means that the eye will see more by focussing correctly for the central pupil than for the outer zones. This is an added factor which weights the center of the pupil. At scotopic levels, however, vision is much less acute and the outer zones should be capable of approximately the same resolution as the inner zones and hence, the resolving characteristics of the eye do not tend to the inner zones.

6. Departure from sharp focus extrafovealy may influence nighttime vision if the retina is not properly curved to follow the field of the optical system of the eye, for scotopic vision uses the extrafoveal areas of the retina and photopic uses the fovea. It is not known whether this effect is important or whether it tends to produce or reduce nocturnal myopia.

7. Accommodation, if present, will produce nocturnal myopia.

8. In binoculars accommodation, compensated for by the adjustment of the binocular, results in a slight increase of magnification. It is not known whether this results in improved vision.

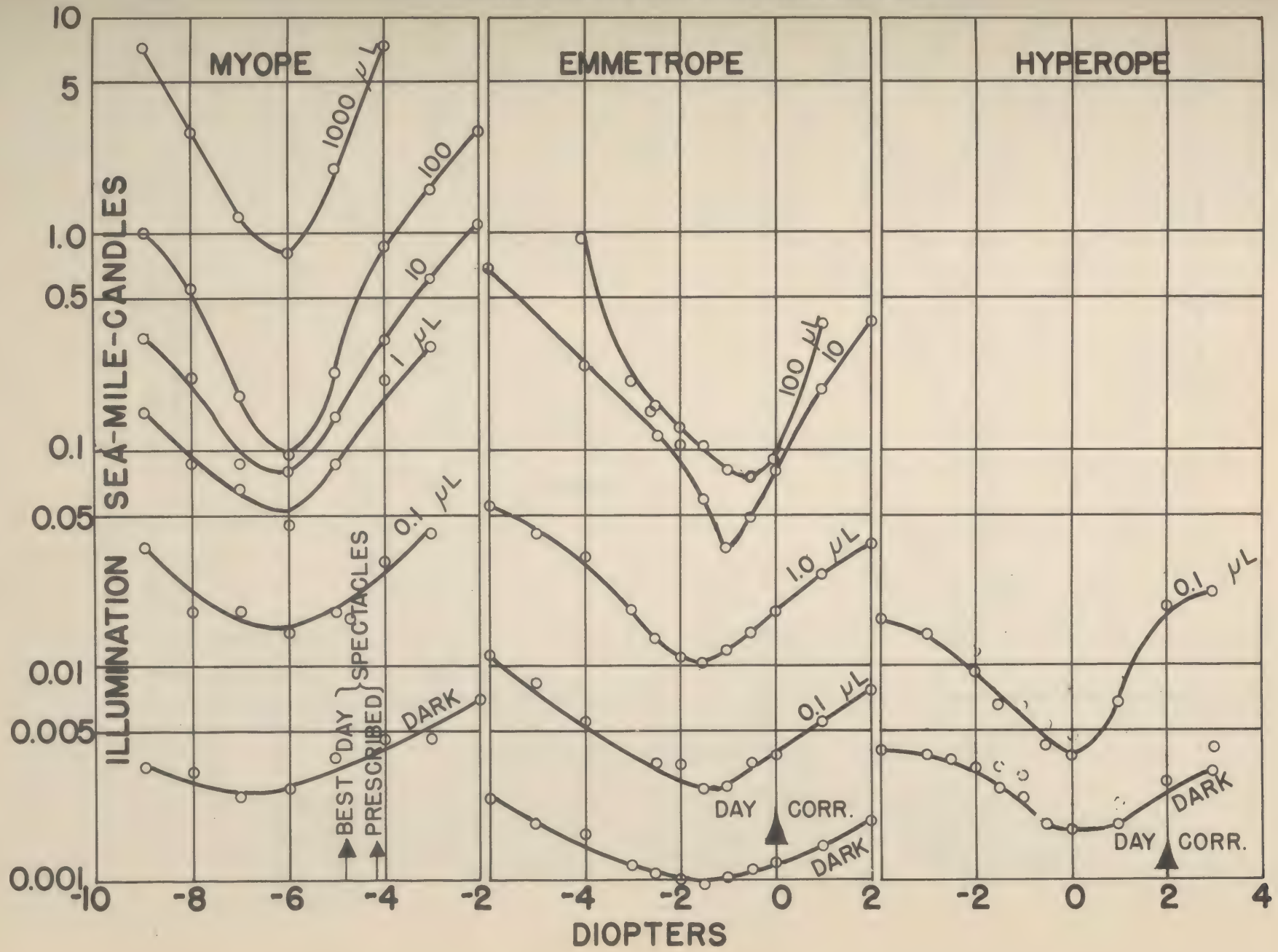
We are continuing the experiments to try to separate the parts played by these effects in producing nocturnal myopia. We have made up a set of annular diaphragms of equal areas in order to measure the spherical aberration of the eye. Preliminary results show that the spherical aberration for the outer zones ranges from -1 to -2 diopters or even more. We are making acuity threshold measurements through these annular pupils and also using monochromatic target illumination in order to separate the effects of chromatic and spherical aberration. Preliminary work indicates that the effect of spherical aberration is a little larger than that of chromatic aberration and that together they account for most of the observed nocturnal myopia.

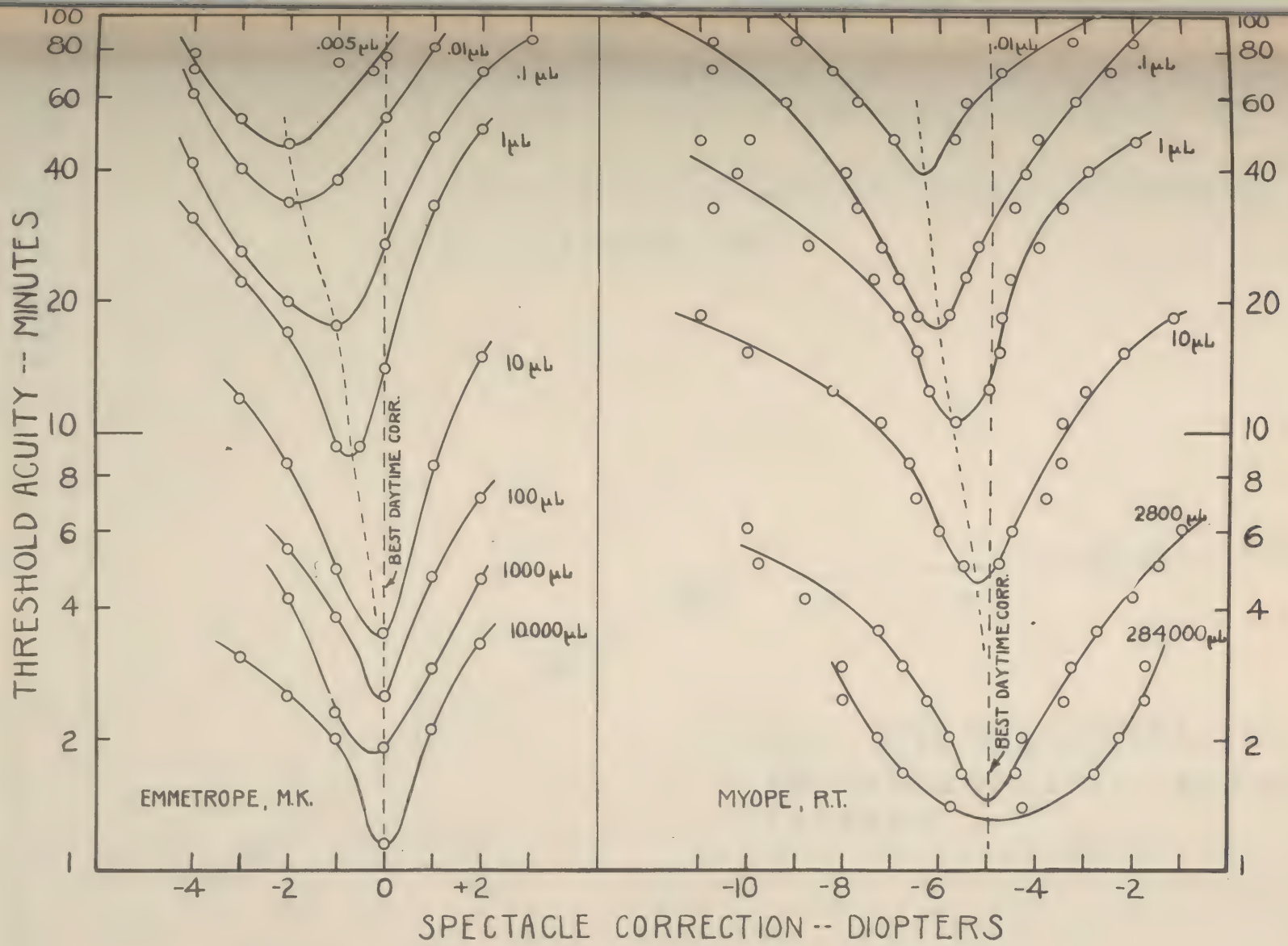
DISCUSSION:

Dr. Wald remarked that the range gains shown by Dr. Tousey as a result of minus lens were much larger than the gains shown in the British work.

Dr. Tousey replied that the range gains were entirely a function of the kind of target used.

FIGURE 1


POINT SOURCE THRESHOLDS
MYOPE
EMMETROPE
HYPEROPE
ILLUMINATION SEA-MILE-CANDLES
10
5
1.0
0.5
0.1
0.05
0.01
0.005
0.001
1000 μL
100
10
1 μL
0.1 μL
DARK
BEST DAY
PRESCRIBED SPECTACLES
100 μL
10
1.0 μL
0.1 μL
DAY CORR.
DARK
0.1 μL
DAY CORR.
DARK
-10
-8
-6
-4
-2
-4
-2
0
2
-2
0
2
4
DIOPTERS



ACUITY vs. SPECTACLE CORRECTION AT VARIOUS BRIGHTNESS LEVELS. GRATING TEST OBJECT SUBTENDING 4°; BRIGHT SURROUND SUBTENDING 14°. ILLUMINATION 2850°K.

FIGURE 2

FIGURE 3

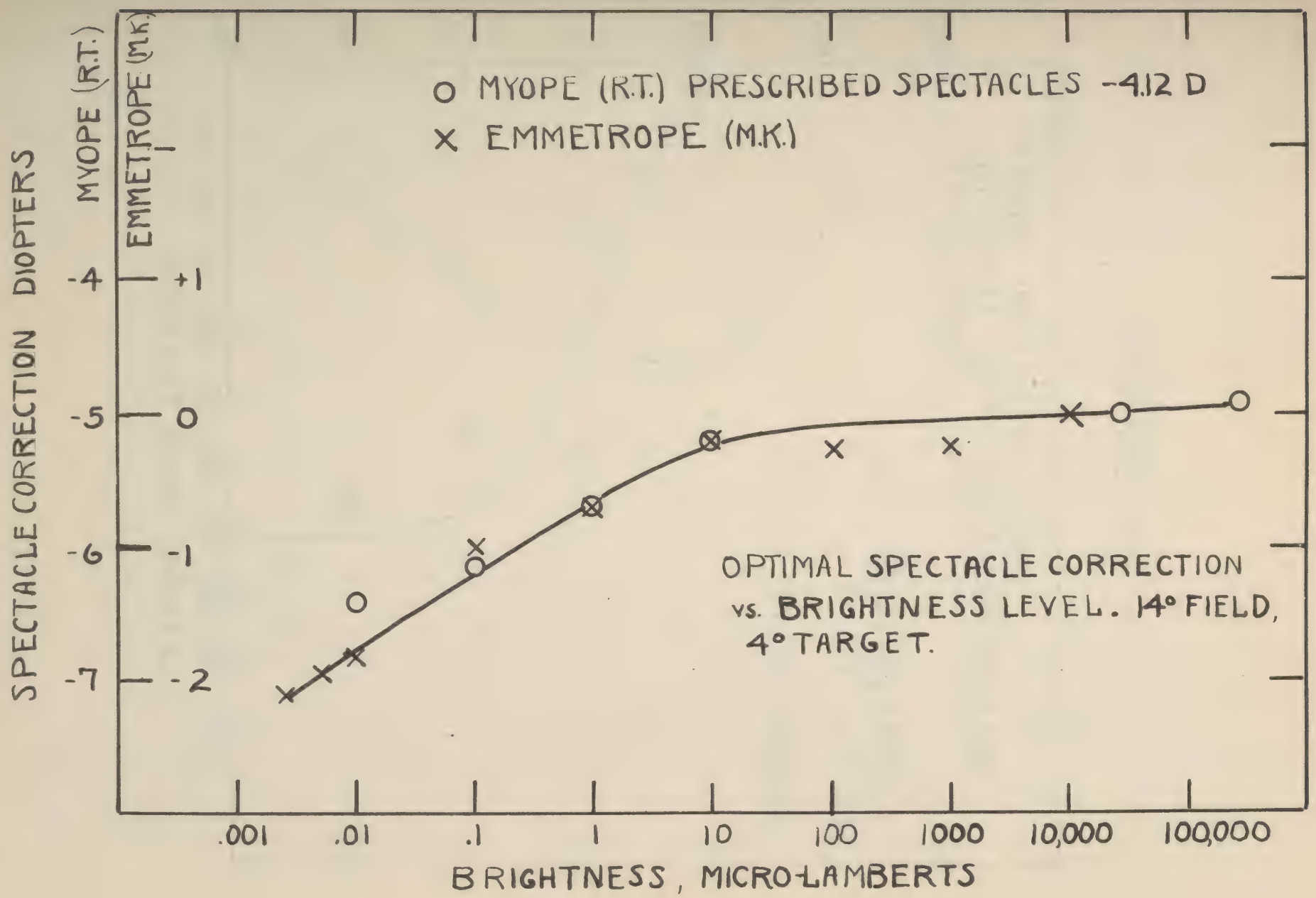
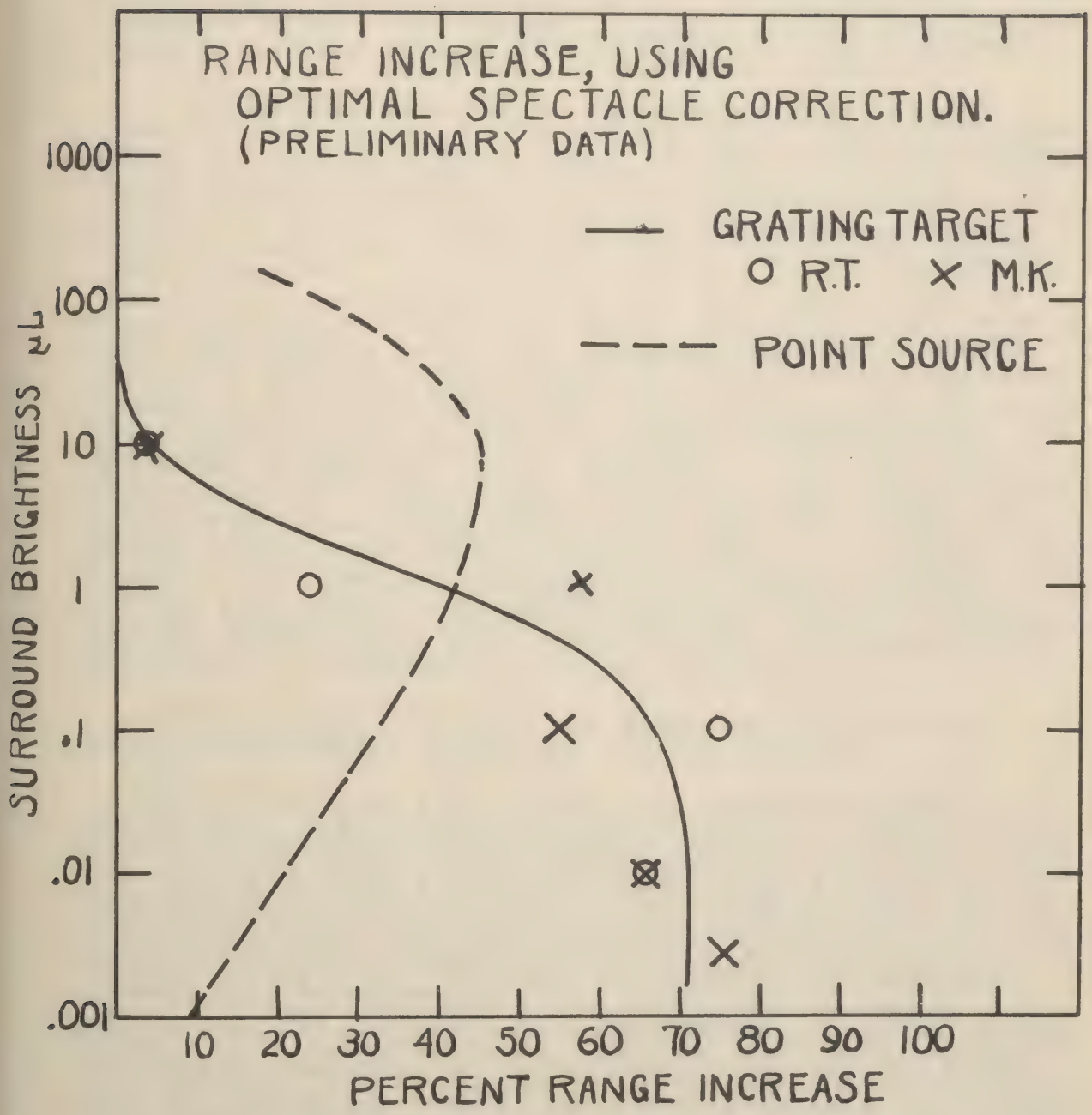

O MYOPE (R.T.) PRESCRIBED SPECTACLES -4.12 D
X EMMETROPE (M.K.)
SPECTACLE CORRECTION DIOPTERS
MYOPE (R.T.)
EMMETROPE (M.K.)
-4
-5
-6
-7
+1
0
-1
-2
OPTIMAL SPECTACLE CORRECTION
vs. BRIGHTNESS LEVEL. 14° FIELD,
4° TARGET.
.001
.01
.1
1
10
100
1000
10,000
100,000
BRIGHTNESS, MICRO-LAMBERTS

FIGURE 4


RANGE INCREASE, USING
OPTIMAL SPECTACLE CORRECTION.
(PRELIMINARY DATA)
GRATING TARGET
O R.T. X M.K.
POINT SOURCE
SURROUND BRIGHTNESS μL
1000
100
10
1
.1
.01
.001
10 20 30 40 50 60 70 80 90 100
PERCENT RANGE INCREASE

CURRENT STUDIES IN COLOR VISION

Lt. Comdr. Dean Farnsworth

A period of war accelerates the kind of studies which can be made quickly and retards the development of researches without immediate application. It is also a period of frantic drain on the stores of fundamental knowledge accumulated during more leisurely periods. In World War II, fairly complete answers were found to certain limited problems in color vision and no progress was made on others.

One problem on which we are almost ready to close the research books is that of designing simple, reliable instruments for testing color anomalous vision in the Navy. All types of tests, represented by over forty individual instruments, and including Army, Navy and Air Corps and foreign devices, have been investigated in the New London Color Vision Laboratory. Let us review the decisions: (1) Color vision tests for general use in the Navy should have a sharp pass-fail cutoff. (2) They should give reliable results when administered by slightly trained personnel. (3) They should be as nearly unlearnable as possible. (4) Two tests should be available, a screening and a selection test. (5) The screening test should be so sensitive that no color-deficient person will escape detection. (6) The selection test should be less stringent so that the near normal and color weak (about 2% of males) will pass, but it should positively identify the definitely color defective (without arguments). (7) Pseudo-isochromatic test plates containing numbers have proved most satisfactory for general screening, and the lantern-type test, after extended development, has proved most satisfactory for final selection.

We may here list the ideal characteristics for the pseudo-isochromatic plates and for the lantern:

The requisites for an ideal set of pseudo-isochromatic plates are: (1) To prevent easy learning, the dot pattern should be the same, or confusingly similiar, for all plates; (2) the dark, middle and light colors should appear in the same positions in all plates; (3) The numbers should be simple in design; (4) Many "reversible numbers" plates should be included; (5) in order that no variants from ordinary anomaly fail to be detected, one set of plates should be chosen from the confusion zone for deutans (so-called "green-blind") with high macular pigmentation, and one set should be designed according to the characteristic luminosity function of protans (so-called "red-blind"); (6) Since the colors of polychromatic plates are necessarily a function of their illumination, a standard lamp should be supplied for their illumination.

The diagnostic principles of lanterns and their operation have been analyzed in the project reports on that subject (X-457) released this week by BuMed. The colored lights in a test-lantern are not just any red, white and green, or even the standard colors of signal lights: (1) It is important that the red, white, and green shown should be colors with the same amount of yellow and blue in each, else the red-green defective may learn to pass a particular test-lantern by the yellowness or blueness of the light. (2) Three properly selected colors will sample the degree of color deficiency throughout the whole chromatic range; more than three are unnecessary and are confusing to the operator. (3) If colors are shown in pairs, one of which is slightly darker than the other, a red-green defective will reveal his dependence upon brightness in naming colors. (4) Colors should be displayed at a very small visual angle because the fovea is the most color-sensitive region of the retina and therefore displays the maximum differentiation between the color normal and the anomalous.

The two tests are in three ways complements to each other: the plates test the broader para-foveal region, the lantern tests central vision; the plates test the form-color sense without color naming, the lantern tests color recognition; the plates are sensitive detectors of color anomaly, the lantern simulates requirements of service at sea. Pseudo-isochromatic plates are sometimes thought to be too sensitive, in that they detect slight deviations from normal and are sometimes difficult for normals. This is a safety factor and is not a drawback if they are used simply for rough screening. From the Service standpoint, a good lantern has the added value of "face validity" because an examinee's failure to distinguish bright, simple colors makes the defect so very evident to the examiner. In these two tests, we believe that we have the specifications for effective Service tests ready for production.

However, now that specifications for tests are ready, I propose that the next project of the Committee be to further the study of how we may discard them. For military and sociological economy, this project should have the highest priority among color studies. Knowing that 9 out of 100 men are color deficient, various agencies are starting to design or redesign signals and codes so that normal color vision is unnecessary for certain occupations. Consider traffic signals: A vertical bar is used for "go", round for "caution", and horizontal for "stop." For wire coverings: Barred combinations of black, white, blue, and orange (which all color defectives distinguish). For all occupations in the laboratory, the shop, at sea, in the home--study has found, or will usually reveal, a type of noncolor code, which can be added to the existing signals. Blinkers, patterns, numbers, letters, positional and yellow-blue series are already in use.

A residue of special occupations will be found which require normal vision, some which demand only rudimentary color ability, and a few to which the highest discriminations are necessary. Tests exist for all of these classes but they await development and validation for the purposes to which they are to be applied. Two degree-of-deficiency types of test in the normal-to-anomalous range are anomaloscopes and threshold lanterns. There are dichotomizing tests which will segregate moderate from extreme color deficiency.

The study which almost everyone has demanded is a job analysis or evaluation of how much color vision is required for the safe performance of duties in various occupations and branches of the Service. This study will be complicated by the changing duties of rates and ranks, the quickly shifting modes and instruments of warfare, and it must be related to existing regulations which embody physical requirements not involved in the duties of the rate or corps. This will have to be a major undertaking--color judgements made in the field are not simple responses but are complex reactions of the individual. Piecemeal or simple laboratory experiments will not suffice.

The color problems that await further attack may be counted in scores or hundreds depending upon how they are grouped. Let us mention three problems that are under investigation by members of the Committee and three broad studies which require renewed attack.

1. Protection for the eye against nature's great range of seen and unseen energies has necessitated improvised eye goggles, but we do not know whether we are near the beginning or the end of the problem. The effect of color and density on color discrimination is under study by BuMed , but the effects of peripheral glare on all visual discriminations as compared to the effects of excessive energy reaching the central portion of the retina has not been approached.

2. The most-used portion of the retina, the fovea, demonstrates peculiar and specialized color responses but no quantitative relationships to vision at larger subtense are available nor are the relationships of vision at various subtense to small-color differences known. Techniques created by Wald, Miles, and Wright should furnish a basis for investigation of this critical region.

3. Only two tests for superior discrimination are available. One, the F-M 100-hue test is used by the Army and in certain industries for selecting personnel for color-control positions; the I-S.C.C. "Color Aptitude Test" was originally created by a Committee of the Inter-Society Color Council, in conjunction with representatives of the Army, Navy, and Civil Aeronautics Authority. Each require further development.

[redacted]

There are at least three large familiar lands into which new exploring expeditions should be sent. First of these concerns the determination of the fundamental sensation curves of the eye. Better solutions of this master formula may greatly simplify other problems, including, second, the determination of the relations of the psychophysical color manifold. The third field is the broadest, a scientific investigation of the new art of "color conditioning", color applied to surroundings with a purpose. Preliminary surveys have been made for the Submarine Service and spasmodic trials have been made with larger ships but no methodology has yet been developed for systematic study.

At this time it would be well to enlist the help of private laboratories, universities, the Bureau of Standards, the Inter-Society Color Council, O. R. I., and the various Naval and Army laboratories in setting up a ten-year plan of organized color research.

DISCUSSION:

Lt. Comdr. Imus raised the question whether colored filters could be obtained for haze penetration.

Lt. Verplanck reported observations made in New London to investigate the effectiveness of a series of red, amber, and yellow filters. Using low contrast neutral targets at a range of 8,000 yards, it was found that color had no effect which could not be attributed to the light transmission of the filter.

Dr. Tousey made the interesting point that red filters actually permit a myope to obtain better visual efficiency. He believed it possible that the reported haze penetration of red filters was actually the result of the improved effectiveness for myopes.

Dr. Chapanis raised the question of color specifications for sunglasses. He was dissatisfied with the New London report on the effect of color discrimination through various types of sunglass filters, both because the brightness level used was not sufficiently high and because of the large difference in color temperature of the light in the experiment and ordinary daylight.

Lt. Comdr. Farnsworth reported that color discrimination would depend upon illumination level but the relative discrimination did not change over the different parts of the spectrum. For this reason, the results obtained with a low quantity of daylight illumination should be correct relatively for other daylight illminations.

[redacted]

Dr. Brackett asked whether the general conclusion was that color filters were not useful in military operations.

Lt. Verplanck replied that for special purposes filters were of course often useful, but that for general, neutral targets, no appreciable haze penetration had ever been observed.

Dr. Brackett believed it possible that there were field conditions in which color filters were very useful.

Dr. Miles made the point that filters have a psychological effect in that the scene when altered by the insertion of a filter appears brighter and clearer simply because it is different.

Dr. Wald remarked on the fact that in the development of the higher vertebrate a yellow pigment had been provided for the central retina. This evolutionary development he found hard to understand if the spectral quality of light had no influence upon visual acuity as Luckiesh's data seemed to indicate.

Dr. Marquis asked whether there are requirements for color vision in the services other than the use of color coding, which Lt. Comdr. Farnsworth had proposed eliminating.

Dr. Chapanis reported that the Army Air Forces had found difficulty with the color blind in recognizing signal flares, but that they had never encountered difficulty with color coding even by the color blind.

Dr. Hecht expressed the belief that adequate color discrimination is very critical in aerial observations.

Dr. Burger asked whether there was a loss in general visual functioning by the color blind.

Dr. Hecht replied that although the information had not been published, it had been found in his laboratory that color blinds do actually lose visual capacity to an astonishing extent.

MEMORANDUM CONCERNING THE PROPOSED VISUAL RESEARCH CENTER

It is generally agreed that it is desirable for the Office of Research and Inventions to set up a center for visual research in the United States Navy. The problem is one of setting up such an organization in view of the difficulties encountered in acquiring a suitable location, in the construction of buildings at a time when building materials are in restricted supply, and in assembling a staff when the great majority of those who have done visual research during the war are re-entering the academic field. These problems must be solved by the use of less direct methods than those to which we have become accustomed. But solved they may be if we are content to make haste slowly.

The procedure proposed for the organization of this station herein outlined contemplates that, in veiw of the difficulties noted above, no such station can be put into operation for a period of approximately 24 months. Accordingly, the effort is scaled to that end.

Step 1: A nuclear organizational committee shall be set up by the Office of Research and Inventions, to include ORI and Army-Navy-NRC Vision Committee personnel, and also some of those who may be contemplated as possible future members of the staff. This committee should not exceed six in number.

Step 2: There shall be submitted to this committee by any interested person or group a full outline of the functions, staff and equipment of the proposed organization. This detailed proposal shall merely serve as a starting point which the committee will modify, extend, or amplify as it may deem advisable. The final detailed proposal, prepared by the committee, and as complete as possible, shall be submitted by the committee to the Office of Research and Inventions.

Step 3: In order to interest academic people in the organization, every effort should be made by the committee, to interest a university or research foundation in operation of the organization jointly with the Navy. This should ensure that a staff of the highest calibre can be obtained.

Step 4: The Office of Research and Inventions will submit the proposal to CNO for consideration of joint operations with vessels and aircraft, and to the Bureau of Supplies and Accounts for an estimate of the initial cost of operation of the proposed program, for an estimate of the cost of operation of each part, and for an estimate of the annual budget required.

Step 5: When replies have been received from the universities contacted, from the Bureau of Supplies and Accounts, and from CNO, the nuclear committee shall scan these and re-evaluate

its initial proposals in the light of the answers received. At the same time, a coordinator for the organization shall be appointed. It will be his duty to contact personnel suitable for posts in the proposed center, endeavor to interest them in joining its staff at such time as it becomes operational, and to appoint them temporarily as technical advisors during the period of organization. These technical advisors will work with the coordinator in planning the organization in detail, in planning its buildings and facilities, and in procuring its equipment. The coordinator shall have a staff sufficient to assist him in summarizing all the requirements laid out by the technical advisors and in getting the base selected, the buildings built, and the equipment assembled.

Step 6: When these steps have all been taken, and while construction is underway and equipment being assembled, every effort should be made to transfer the technical advisors from the status of advisors only to full-time staff members. It is believed that if this procedure is followed, it will be possible to set up an organization where vital research--theoretical, applied and field--may be performed under optimum conditions in the general field of vision, and which may well serve as a Wood's Hole for visual research.

VISUAL RESEARCH CENTER

1. The Visual Research Center will be set up jointly by the Office of Research and Inventions, and by a University or civilian Research Foundation. Its activities, policies, and priorities for use of its facilities will be controlled by a board of trustees, half appointed by ChORI, and half by the University or Foundation. It will include representatives of CNO, ComOpDevLant, BuShips, BuOrd, BuPers, BuM and S, and an equal number of civilians, representing such organizations as the Army-Navy-NRC Vision Committee, American Physiological Association, American Psychological Association, the Inter-Society Color Council and so forth.

2. The functions of VRC will include:

(a) to act as a central clearing house and information service on visual data for all naval activities.

(b) to evaluate, experimentally, the applicability to military problems in the field of the results obtained in already established research facilities, both civilian and military.

(c) to test in the laboratory and in the fields:

(1) optical instruments and visual aids already in use by the armed forces, or designed for use by them.

(2) training methods for lookouts and other personnel concerned in visual tasks.

(3) data contained in the nomographs which have been developed for predicting visibility ranges.

(4) visual techniques or doctrines, e.g., of scanning.

(d) to extend existing field data on visibility such as those obtained in studies on submarine visibility by the Camouflage Section, BuShips.

(e) to perform, on request by other naval activities, and on approval of the board of directors, experimentation deemed desirable by those activities.

(f) to initiate visual experimentation--theoretical, applied, or field--for which a need is seen by the staff of VRC.

(g) to provide facilities and advice to personnel of other laboratories desiring to conduct visual researches at VRC.

3. Location: The location of the VRC shall meet the following criteria:

(a) presence of two 10-mile clear ranges, one over water, and one over land, both free from lights for night experimentation.

(b) proximity to a naval base and naval air station so that joint operations with ships and aircraft can be carried out expeditiously.

(c) a climate providing a variety of visibility conditons.

(d) sufficiently far south that winter operations are possible, yet not so far that uncomfortably cold weather never occurs.

(e) accessibility, both in distance and transportation facilities, to personnel from the majority of naval and civilian laboratories.

(f) a tolerable summer climate, in order to attract civilian scientists and students.

4. Equipment and Facilities: The VRC will have, as a minimum, the following specified facilities.

(a) a library which includes copies of all available reports on naval and military visual research, as well as standard journals and works on vision and related fields.

(b) a shop, able to build and service equipment of all kinds, visual targets, photometers, and other equipment.

(c) a statistical office, equipped to perform necessary calculation.

(d) small craft and vehicles for routine operations.

(e) indoor visual ranges, as follows:

(1) a light-tight tunnel or shed, 6'x6' in cross section, and several hundred feet in length.

(2) a short range 80' in length, and 10'x20' in cross section.

(3) a "circus"--a light-tight room 70' x 70' square, or a 120° sector of a circle with a radius of 70 feet.

(f) indoor working space of approximately 2500 square feet. This space available for ad lib temporary partitioning, but equipped throughout with AC, DC, water, and air conditioning vents.

(g) special devices, such as vibration and pitch and roll tables.

(h) a miniature railway (1' gage), with motor driven cars, for manipulation of targets from a distance.

If a naval bureau or other organization requires study of special equipment, it will undertake to provide it to the station for study.

5. Staff: The permanent staff will include:

(a) the director.

(b) three professionally qualified Civil Servants, or equivalent naval officers, to direct and perform experimentation.

(c) an engineer: naval officer or civil servant.

(d) two line officers of junior rank.

(e) six junior professional civil servants, or equivalent naval officers.

(f) ten clerical and statistical personnel.

(g) six shop assistants, including one or two good machinists.

(h) thirty to forty enlisted men, assigned as observers and assistants in experimentation, of specified rates.

If a naval bureau or other organization requests research requiring a larger staff, it shall undertake to provide the additional temporary staff required.

Extra burdens of statistical work may be handled on a contract basis by qualified civilian organizations.

6. Operations: All joint operations with aircraft or ships which are required for experimental work, will be carried out under the Commander, Operational Development Force, U. S. Atlantic Fleet. If it is necessary to undertake field work away from the station, arrangements will be made with the appropriate command.

7. General Duties: One-third of the time and facilities available will be assigned to scientific personnel attached to the laboratory for research of their own choosing. They will receive every assistance in performing such research.

W. S. Verplanck, Lt. (USNR)

DISCUSSION:

Comdr. Brown arose to clarify one point in the discussion. He emphasized that the proposed vision research center was not intended to be merely a continuation of the Visibility Model Camouflage Theatre, but that the function should be far more extensive.

Dr. Brackett expressed the belief that four problems were involved in such an establishment: (1) recognition of the problems arising in the Service. (2) Fundamental research, (3) implementation, (4) field evaluation. He emphasized that it is impossible to rely on men trained for operational duty to recognize the need for research.

Captain Shilling pointed out that the vision research center proposal carried with it the idea that members of the staff "live with" operational units in order to appreciate fully the operational problems.

Captain Korb emphasized the necessity for expression of research results in a way which could be readily understood by the men who operate the Navy.

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PROCEDURES FOR OPERATION OF THE ARMY-NAVY-NRC VISION COMMITTEE

I. MEMBERSHIP.

There will be two classes of membership in the Army-Navy-NRC Vision Committee: Members and Associates.

A. Members. Each of the three constituting organizations will appoint members to the Committee. In the case of the Army and the Navy, members will be appointed representing official service units. The exact number of Army and Navy members will vary somewhat with the changing organization of the Services; it is understood that approximately 15 members will be appointed from each organization. Alternate members will be designated in each case to serve for the members in their absence from Committee meetings.

National Research Council members will be appointed on the basis of their individual competence and interest in the work of the Committee. The number of NRC members is not specified, except that it will not exceed the combined number of Army and Navy members. In case of absence, an NRC member can designate a colleague to act in his stead. Traveling expenses incurred in connection with the work of the Committee will be reimbursed. It is understood that individuals employed primarily by industrial laboratories are not eligible to membership.

Members will be privileged to attend all meetings, receive all publications, and to have franchise in regard to any matters of business of the Committee.

B. Associates. Selected individuals who are not members of the Vision Committee may be designated associates by action of the Executive Committee. The Executive Committee shall review and revise the list of associates on frequent occasions.

Associates will have the right to attend all scheduled meetings of the Vision Committee and to receive all unclassified publications of the Committee. Only upon invitation, however, will traveling expenses be reimbursed. It is understood that individuals employed primarily by industrial laboratories are not eligible for appointment as associates.

II. EXECUTIVE COMMITTEE.

The Executive Committee will consist of nine members, one to be appointed officially by each of the constituting organizations, and six to be elected. Of the six elected members,

[redacted]

two shall be official members from each of the constituting organizations. Election will be by the vote of all the members for a term of two years with rotation. Vacancies on the Executive Committee will be filled by action of the remaining members of the Executive Committee.

The Executive Committee is empowered to act for the Vision Committee subject to the referral of appropriate issues to the Committee and reporting of all decisions to the Committee.

III. OFFICERS.

The Chairman and the Deputy Chairman of the Vision Committee will be elected by the Executive Committee from among the members of the Committee. Both officers will not be selected from the same constituting organization. The term of office will be two years.

DESIGN FOR AN ILLUMINATION SYSTEM FOR THE MARK V SURFACE LOOKOUT ALIDADE

H. Richard Blackwell

Upon the request of H. T. Chase, Capt. (USN), BuShips, the Army-Navy-NRC Vision Committee staff has undertaken to answer the following question: What illumination is required for the Mark V scale to be instantly legible following the scanning of a field of high brightness through binoculars?

The field situation: Men scan the sky and sea through binoculars, often encountering in their visual field high brightnesses such as the sun or the reflection of the sun in the sea. When they attempt to ascertain the position of a sighted object, they are not instantly able to read the alidade scale, positioned as it is in a low brightness area. The feasibility of designing an illumination system for the Mark V to overcome this difficulty has been investigated by analysis of existing experimental data.

The problem can be analyzed into three parts: (1) It is necessary to determine the state of the eye when high brightnesses are encountered in the visual field during scanning. (2) Allowance must then be made for the adaptation occurring in the few seconds between scanning and reading the scale. (3) The scale brightness necessary for legibility can be computed from the effective condition of the eye at the moment of reading the alidade scale. In this computation, the alidade scale is projected upon a field of brightness equivalent to that to which the retina is adapted.

(1) In the simple case in which the men look directly at a high brightness source before turning to the alidade scale, the effective adaptation brightness is of course the brightness of the source. Men will probably never gaze directly at the sun because of the extreme discomfort experienced. It is possible that they will gaze directly at the reflection of the sun from the sea, which has a brightness as high as 1,000,000 footlamberts.

In most cases, the line of sight is directed some distance away from high brightness sources in the visual field. In order to ascertain the effective foveal brightness adaptation under these conditions, use must be made of an empirical equation derived from a number of studies of non-uniform visual fields.[1] It must be emphasized that these data apply only to cases in which the glare sources are not imaged on

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1. Moon, P. and Spencer, D.E.: The Visual Effect of Non-uniform Surrounds, J.O.S.A., 35, 233 (March 1945); Stiles, W.S., and Crawford, B.H., Proc. Roy. Soc., B, 116, 55, (1934); Stiles, W.S., Proc. Roy. Soc., B, 104, 322, (1929); Holliday, L.L., J.O.S.A., 12, 271, (1925).

[redacted]

on any portion of the foveal retina. The experimental data can best be summarized by the following equation:

$$B_a = B_s + \frac{9.6 \times 10^{-3}}{\pi \theta^2} E_G \qquad [1]$$

where:

B_a = effective adaptation brightness (footlamberts)

B_s = surround brightness (footlamberts)

E_G = illumination on a plane perpendicular to the line of sight from the glare souce (lumens/ft^2)

θ = angle between glare source and line of sight (radians)

Because of the difficulty of estimating E_G, a most useful form of the equation is:

$$B_a = B_s + \frac{9.6 \times 10^{-3} B_G}{\pi \theta^2} \cos \theta \, \Delta \omega \qquad [2]$$

where:

B_G = glare source brightness (footlamberts)

$\Delta \omega$ = solid angle subtended by glare source (steradians)

Calculations have been made from equation [2] to estimate the effective foveal brightness adaptation under various field conditions. Glare sources have been selected whose image either covers completely the foveal retina or does not cover it at all. The calculation when the image of the glare source covers only a portion of the fovea is complex, and data thus obtained do not alter the general solution to the problem.

Case I: Sun

Calculations were made to determine the effective foveal brightness adaptation with the line of sight directed at various distances from the sun. A brightness of 4 x 10^8 footlamberts and angular subtense of 32 minutes of arc were assumed. In Table I below, effective foveal brightness adaptation (B_a) is presented as a function of the angle separating the sun from the line of sight. (θ)

[redacted]

TABLE I

θ (degrees)	Ba (footlamberts)
1°	315,000
2°	86,200
3°	43,700
4°	29,100
5°	22,200
10°	13,050
20°	10,760

Case II: Sea Reflection

The effective foveal brightness adaptation was computed for cases in which a reflection from the sea was present in the visual field. Various values for the area of sea reflections ($\Delta\omega$) and different values for the angle between the center of the reflection area and the line of sight (θ) have been used.

TABLE II

θ	Ba (footlamberts) $\Delta\omega = 0.000308$*	$\Delta\omega = 0.00122$**	$\Delta\omega = 0.00491$***
1°	13,050	(1,000,000)	(1,000,000)
2°	10,760	13,040	(1,000,000)
3°	10,340	11,350	15,400
4°	10,191	10,758	13,040
5°	10,122	10,486	11,950
10°	10,030	10,121	10,486
20°	10,008	10,030	10,121

It is apparent that the effective foveal brightness adaptation at the moment before removing the eyes from the binoculars will vary from the brightness of the sky to the brightness of the sea reflection itself.

(2) The second phase of the calculation involves the change in foveal brightness adaptation during the few seconds between the end of scanning and the glance at the alidade scale. Considerable experimental data are available demonstrating the adaptation of the fovea to change in brightness conditions.[2]

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* 1 degree on a side.
** 2 degrees on a side.
*** 4 degrees on a side.

2. For example, Hecht, S., C. Haig and A.M. Chase. J. Gen. Physiol. 1937, 20: 831-850.

No experimental data have ever been obtained, however, which are directly pertinent to the problem at hand. General field brightnesses have never been investigated greater than approximately 1,000 footlamberts. Further, it is customary for a completely dark field to be used in measuring the rate and extent of adaptation.

By means of reasonable assumptions and extrapolation of existing data, an estimate of the probable adaptation was obtained. It seems likely that approximately 50 seconds are required for the retina to decrease the effective foveal brightness one log unit through the process of adaptation. If this is true, the few seconds separating exposure to high brightness and examination of the scale do not permit any appreciable change in the effective foveal brightness adaptation. As a first approximation, therefore, the values of Ba contained in Tables I and II, can be considered the effective adaptation brightnesses at the moment of viewing the scale.

It is possible that this interpretation is not wholly justified. Dr. H. K. Hartline has expressed the belief that a fundamentally different process is involved in the first few seconds of adaptation than in the subsequent adaptation. If recovery during the first few seconds following exposure to glare is an important problem for the Navy, it is recommended that research be undertaken to determine the rate and extent of this adaptation. For the purpose of designing an illumination system, however, neglecting the possible adaptation serves only to provide a conservative design.

In the third step of the analysis, the scale brightness is computed which will be legible with known foveal brightness adaptation. As a useful first approximation, the scale will be legible when the brightness of the numbers and lines equals 10% of the brightness to which the eye is adapted. We have assumed above that when the eye is directed from scanning to reading the scale no appreciable adaptation occurs; the eye is adapted approximately as it was during scanning. The brighter elements of the alidade scale must have a brightness which would make them visible if they had been projected on the scanned field. Experimental data[3] indicate that the numbers and lines of the alidade scale should be approximately 10% brighter than the surrounding field to be legible.

The brightnesses of the alidade scale which will be necessary for it to be clearly legible under various conditions are presented in Tables I-a and II-a below. The values in these tables are simply 10% of the values presented in Tables I and II above.

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3. For example, the Tiffany Foundation visibility data. See the report, "Visibility of Targets," OSRD No. 6401, October 1, 1945.

TABLE I-a

θ (degrees)	Ba (footlamberts)
1°	31,500
2°	8,620
3°	4,370
4°	2,910
5°	2,220
10°	1,305
20°	1,076

TABLE II-a

θ	Ba (footlamberts) $\Delta\omega = 0.000306$*	$\Delta\omega = 0.00122$**	$\Delta\omega = 0.00491$***
1°	1,305	(100,000)	(100,000)
2°	1,076	1,304	(100,000)
3°	1,034	1,135	1,540
4°	1,019	1,075	1,304
5°	1,012	1,048	1,195
10°	1,003	1,012	1,048
20°	1,000	1,003	1,012

It is recommended that the lines and numbers of the alidade scale be transilluminated and that the remainder of the scale be as dark as possible. Several theoretical considerations lead us to expect greater legibility under these circumstances. For example, the numbers can have greater contrast if they are bright and the surround dark than vice versa. The brightness surrounding the alidade scale, however, is not very important in that the increase in legibility with decrease in this brightness is slight.

The data in Tables I-a and II-a indicate that the lines and numbers of the alidade scale should be made as bright as possible. A scale brightness of approximately 2,000 footlamberts would be adequate for many cases. A maximum brightness of approximately 20,000 footlamberts could be obtained by using a relatively high candlepower lamp with reflector, illuminating at an extremely short distance a flashed opal

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* 1 degree on a side.
** 2 degrees on a side.
*** 4 degrees on a side.

glass positioned immediately under a transparent scale. Tables I-a and II-a can be used to estimate the conditions under which this scale will be immediately legible.

The data in Tables I-a and II-a are undoubtedly conservative and adaptation from glare may be sufficiently rapid so that additional field situations can be served by the illuminated alidade scale. It seems likely that it will be impractical to develop an alidade scale to be read immediately after gazing at the sun, at the sea reflection of the sun, or in the special cases indicated in Tables I-a and II-a in which extremely high brightnesses exist near the line of sight.

THE EFFECT OF ANOXIA UPON VISUAL PERFORMANCE

H. Richard Blackwell

Various reports in the files of the Army-Navy-NRC Vision Committee are concerned with the effect of anoxia upon visual performance under various conditions. A brief survey of these indicates that the field conditions investigated are so divergent that safe generalization is not possible. For this reason, it is believed that the most accurate estimate of the effect of anoxia upon visual performance can be obtained from laboratory studies which were conducted during the war.

Reference is made to the experimental study entitled "The Effect of Anoxia on Visual Contrast Discrimination," CAM Report No. 184, 15 August 1943, by S. Hecht, C. D. Hendley, and S. Frank. This report presents data indicating the contrasts required for visual discrimination under normal conditions and under various conditions of oxygen deprivation. In the Hecht investigation, the test object was a broken circle, the diameter of which subtended 7.5° and the break 1.5°. Binocular observations were made at three brightness levels and for oxygen concentrations corresponding to altitudes from normal to 17,000 feet.

In order to ascertain the significance of the losses in contrast discrimination as a function of anoxia demonstrated in the Hecht report, it is necessary to utilize data relating threshold contrasts to target range. Such data were obtained at the Tiffany Foundation. (See "Visibility of Targets, OSRD No. 6401, October 1, 1945.) Laboratory results are available relating threshold contrast, target range, and brightness level. Nomographic charts have been prepared in which both the laboratory results on contrast thresholds and theoretical formulations of the effect of the atmosphere upon contrast are combined. The nomographic charts permit the calculation of the threshold range of a target of known size and contrast at a specified sky brightness and atmospheric condition.

Calculations have been made from the nomographic charts to determine the effect of loss in contrast discrimination due to anoxia, in terms of reduction in target range. The calculations presented below represent a few critical cases. If additional information on special problems is desired, such calculations can be made easily from the nomographic charts.

Results:

At a specified brightness level, a unit loss in contrast discrimination will produce the greatest loss in target range for targets of low contrast. The effects of anoxia are more significant for clear atmosphere than for clouded atmosphere.

In the following tables, threshold target ranges are presented for oxygen concentrations corresponding to various altitudes. For each altitude, the range is expressed as a decimal of the range of the target at normal altitude. (The same relative ranges are obtained regardless of the physical size of the target. Varying the size of the target merely changes the absolute range but does not alter the fundamental relation between visual subtense of the target and threshold contrast upon which the effect of anoxia is based.)

Table I: Sky Brightness = 1×10^{-1} footlamberts

Target Ranges Relative to Normal Oxygen

Altitude (ft.)	Unlimited Visibility Target Contrast			2 Mile Visibility
	1.0	0.1	0.02	0.02
6,200	0.976	0.974	0.987	0.995
8,600	0.945	0.950	0.900	0.985
11,500	0.910	0.908	0.844	0.962
13,200	0.877	0.877	0.779	0.934
15,300	0.864	0.853	0.729	0.917
17,000	0.749	0.759	0.519	0.845

Table II: Sky Brightness = 1×10^{-2} footlamberts

Target Ranges Relative to Normal Oxygen

Altitude (ft.)	Unlimited Visibility Target Contrast			2 Mile Visibility
	1.0	0.1	0.04	0.04
6,200	0.990	0.988	0.982	0.995
8,600	0.950	0.952	0.920	0.976
11,500	0.870	0.818	0.757	0.908
13,200	0.810	0.726	0.535	0.864
15,300	0.776	0.675	0.491	0.831
17,000	0.740	0.613	0.421	0.815

Table III: Sky Brightness = 1 x 10^{-3} footlamberts

Target Ranges Relative to Normal Oxygen

Altitude (ft.)	Unlimited Visibility Target Contrast		2 Mile Visibility
	1.0	0.1	0.1
6,200	0.965	0.875	0.960
8,600	0.880	0.734	0.909
11,500	0.862	0.690	0.897
13,200	0.714	0.417	0.784
15,300	0.676	0.366	0.744
17,000	0.635	0.334	0.721

Typical data presented in the tables above indicate that large reductions in range as a function of anoxia exist only for clear atmosphere and low contrast targets. The military services can conclude from these data whether supplementary oxygen is necessary under certain specified operational conditions.

Recommendations:

In the above calculations, several assumptions have been made which should be investigated. In the first place, the assumption has been made that the relative effect of anoxia is the same regardless of the visual subtense of the target. The data of Hecht, Hendley, and Frank were obtained with a large test object. The calculations, however, assumed that the same relative effect would have been obtained with smaller targets. It is conceivable that the effect of anoxia would depend somewhat upon the size of test objects; the validity of the calculations presented herein depends upon the validity of this assumption. In addition, the Hecht data were obtained with red light. A supplementary check should be made to ascertain that the same relative values are obtained with light of different spectral quality.

It is especially recommended that investigations be made of the relative effect of anoxia upon contrast discrimination at brightness levels smaller than those investigated by Hecht. The data obtained by Hecht indicate an increasingly large effect for increasingly small brightness level. Since brightnesses significantly smaller than those investigated are actually encountered in military operations, extension of the data to include these low brightnesses is very desirable.

If a research program were established to investigate further the effect of anoxia on visual performance, it is recommended that the following procedures be followed:

1. Only relative contrast thresholds be obtained since data already available make possible the interpretation of such relative values.

2. "White" light be used of known spectral quality.

3. Observers be allowed to use foveal or parafoveal vision, whichever they found most sensitive.

THE EFFECT OF SMOKE SCREENS UPON TARGET VISIBILITY

H. Richard Blackwell

During the war years, various research projects were conducted to assess the fundamental functioning of normal human vision. It is believed that a study of these reports, together with theoretical consideration involving the effects of the atmosphere will permit prediction of the effectiveness of various types of smoke screens.

Preliminary results of an analysis being made by the Vision Committee staff indicate that there is excellent agreement between the results obtained in various laboratories concerning the visibility of targets. The following treatment of the effect of smoke screens will be based upon the largest available collection of pertinent data, those obtained by the Louis Comfort Tiffany Foundation, under contract to NDRC Section 16.3. A more complete report of the laboratory results obtained by the Tiffany Foundation can be found in the report: Visibility of Targets, OSRD Report 6401, 1 October, 1945.

The major premise of this report is that the effect of smoke screens upon the visibility of targets resolves to the effect of smoke upon the contrast of the target. It is obvious that an extended smoke screen, whose brightness differs from that of the sky produces also a change in the brightness adaptation level of the eye. Laboratory results reported by the Tiffany Foundation indicate that under normal daylight conditions, the function of the eye is not affected by changes in adaptation amounting to two or three orders of magnitude. This fact is considered justification for the assumption that the sole effect of smoke is to reduce target contrast.

The contrast of a target against the horizon sky can be computed by the following equation:

For a target darker than the background:

$$\text{Contrast} = \frac{[\ B_h A_h + B_p A_p\ ] - [\ B_t A_t + B_p A_p\ ]}{[\ B_h A_h + B_p A_p\ ]}$$

where:

B_h = brightness of horizon sky

A_h = area of horizon sky unobscured by smoke screen (fractional units)

B_t = target brightness

A_t = target area unobscured by smoke screen (fractional units)

B_p = smoke screen-particle brightness

A_p = area of smoke screen-particle (fractional units)

For targets brighter than the background:

$$\text{Contrast} = \frac{[\ B_t A_t + B_p A_p\ ] - [\ B_h A_h + B_p A_p\ ]}{[\ B_h A_h + B_p A_p\ ]}$$

The atmosphere influences the visibility of targets by reducing the target contrast, whether or not a smoke screen is used. The exact effect of the atmosphere is perhaps best expressed by a variation of Koschmeider's formula proposed by Dr. S. Q. Duntley in the Summary Technical Report of the Camouflage Section of NDRC. The form of equation is:

$$C_x = C_o\ e^{-Bx}$$

where:

C_x = contrast of target at distance X

C_o = contrast of target at zero distance

x = distance

B = coefficient of atmospheric attenuation

The range at which a target is just barely visible, that is, can be detected with a probability 50% greater than that attributable to chance, can be computed from the basic laboratory data concerning visual functioning, together with target contrasts computed from the equations given above with reference to the effect of smoke screens and the effect of the atmosphere. A convenient method for computing target range is available in the form of nomographic charts, presented in the Summary Technical Report of the Camouflage Section of NDRC. In using such a nomograph, the target contrast is first computed, due allowances being made for the influence of the appropriate smoke screen. The resultant target contrast is read from the scale on the right-hand side of the nomograph. The target area is determined together with the condition of the atmosphere, expressed in yards of meteorological range. (This concept is used for the convenience of meteorologists; the meaning is that a large black object is just visible a distance called the meteorological range.) A straight edge is used to connect the target contrast with the selected meteorological range. The distance at which the target in question will be seen is read from the intersection of the straight edge and curve representing the target area.

Examples: In order to illustrate the usefulness of this method of determining the effect of smoke screens, several examples will be given.

Case 1. Let us assume broad dylight with a horizon sky brightness equal to 1,000 footlamberts. The area of the target is assumed to be 1,000 ft^2. The target, darker than the horizon sky, has a contrast of 1.0, which means that the target brightness is equal to 0. Consider that the meteorological range equals 20,000 yards. The formula for computing contrast simplifies to:

$$C = \frac{Bh - Bt}{Bh}$$

The ranges at which the target is just detected are presented in Table I for various values of B_p and A_p.

[redacted]

TABLE I

B_p	A_p	C	Range (yards)
10 ft-L	0.10	1.0	17,000
100	0.10	0.99	17,000
1000	0.10	0.90	16,800
2000	0.10	0.82	16,500
10	0.50	0.99	17,000
100	0.50	0.91	16,800
1000	0.50	0.50	15,000
2000	0.50	0.33	13,900
10	0.90	0.92	16,800
100	0.90	0.53	15,000
1000	0.90	0.10	10,500
2000	0.90	0.053	8,500
10	0.95	0.84	16,700
100	0.95	0.34	14,000
1000	0.95	0.05	8,500
2000	0.95	0.026	6,700
10	0.98	0.67	16,000
100	0.98	0.17	11,800
1000	0.98	0.02	6,000
2000	0.98	0.01	4,000

Analysis of visual functions reveals that the largest percentage reduction in target range for given values of B_p and A_p results when the target contrast is small. Accordingly, Case II will consider a target with relatively small contrast.

Case II. The target whose area is 10,000 ft.^{2} has a contrast of 0.10 with respect to the horizon sky whose brightness is 1,000 ft. lamberts. The meteorological range is again considered to be 30,000 yards. Threshold ranges are presented in Table II.

[redacted]

TABLE II

B_p	A_p	C	Range
10	0.10	0.10	15,000
100	0.10	0.099	15,000
1000	0.10	0.090	14,900
2000	0.10	0.082	14,200
10	0.50	0.099	15,000
100	0.50	0.091	14,900
1000	0.50	0.050	12,500
2000	0.50	0.033	11,000
10	0.90	0.092	14,900
100	0.90	0.053	12,600
1000	0.90	0.010	5,500
2000	0.90	0.0053	3,000
10	0.95	0.084	14,500
100	0.95	0.034	11,000
1000	0.95	0.005	2,800
2000	0.95	0.0026	- 0 -
10	0.98	0.067	13,700
100	0.98	0.017	8,000
1000	0.98	0.002	- 0 -
2000	0.98	0.001	- 0 -

The effect of increasingly cloudy atmosphere is to minimize the obscuration effect of smoke screens. Accordingly, the most pronounced variation in range with smoke will occur for absolutely clear atmosphere and small contrasts. Case III is designed to illustrate the maximum effect of smoke screens.

Case III. All conditions for Case III are identical to those of Case II, except that the visibility is considered to be unlimited. The ranges of detectability are presented in Table III.

TABLE III

B_p	A_p	C	Range
10	0.10	0.10	82,000
100	0.10	0.099	82,000
1000	0.10	0.090	80,000
2000	0.10	0.082	75,000
10	0.50	0.099	82,000
100	0.50	0.091	80,000
1000	0.50	0.050	60,000
2000	0.50	0.033	50,000
10	0.90	0.092	81,000
100	0.90	0.053	63,000
1000	0.90	0.010	27,000
2000	0.90	0.0053	16,000
10	0.95	0.084	80,000
100	0.95	0.034	50,000
1000	0.95	0.005	14,500
2000	0.95	0.0026	- 0 -
10	0.98	0.067	70,000
100	0.98	0.017	37,000
1000	0.98	0.002	- 0 -
2000	0.98	0.001	- 0 -

In order to contrast the relative effectiveness of smoke screens in the three cases considered, relative ranges are presented in Table IV.

TABLE IV
Relative Ranges

CASE I	CASE II	CASE III
1000	1.00	1.00
1.00	1.00	1.00
0.99	0.99	0.98
0.97	0.95	0.91
1.00	1.00	1.00
0.99	0.99	0.98
0.88	0.84	0.73
0.82	0.74	0.61
0.99	0.99	0.99
0.88	0.84	0.77
0.62	0.37	0.33
0.50	0.20	0.20
0.98	0.97	0.98
0.82	0.74	0.61
0.50	0.19	0.18
0.39	0.00	0.00
0.94	0.92	0.85
0.70	0.54	0.45
0.35	0.00	0.00
0.24	0.00	0.00

CONCLUSION:

A theoretical treatment has been given of the effect of smoke screens upon the contrast of targets. The effectiveness of the variations in contrast can be evaluated only in terms of fundamental data concerning the functioning of the human eye. Such data are available with sufficient precision for most problems.

MANIPULATION OF TIFFANY VISIBILITY DATA FOR USE IN PREDICTING THE EFFICIENCY OF BINOCULARS

H. Richard Blackwell

The naked eye visibility data obtained by the Brown University binocular testing program (OSRD Report No. 6128) were of necessity limited to a few experimental values. In the Johnson Foundation analysis of binocular performance, the need arose for accurate naked eye visibility data for a wide range of retinal illumination values and target areas. A special interpolative technique was developed, and was reported in OSRD Report No. 6099. The Brown naked eye data are much less extensive than the Tiffany naked eye visibility data. Accordingly, an appropriate manipulation of the Tiffany data should prove useful in further calculations of the expected performance of binoculars.

The quantities which have proved of value in the prediction of the efficiencies of binoculars are retinal illumination values, computed from field brightness and pupillary diameter of the human eye. Tiffany visibility data were converted into retinal illumination values by means of the average pupillary diameters reported by the British (ARL/N2-0.502). Tiffany visibility data from two experimental programs were treated in this fashion. The data of the first program, (Program A) represent a relatively short, typical search. The observers scanned an orbit of 15 degrees within a period of six seconds. The data of the second program (Program B) represent an indefinitely long search, corresponding to several minutes of scanning a 15 degree orbit.

In Figure 1, the Tiffany data of Program A have been converted into retinal illumination units by multiplying field brightnesses and pupillary area. The unit of retinal illumination is the resultant of brightness in footlamberts and pupillary area in square millimeters. In this plot, no correction has been made for the Stiles-Crawford effect. The ordinate represents a quantity useful for binocular predictions, the product of the increment of retinal illumination, ΔI, and Ω, the solid angle subtended by the target in steradians. Curves are presented for targets with five different areas. Corresponding data are presented in Figure 2, for the Tiffany data of Program B. In this case, seven target areas are represented.

The curves of Figures 1 and 2 are valid only if the Stiles-Crawford effect is ignored. Crawford* has shown that the

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*Crawford, B. H., Proc. Roy. Soc. B124, 81 (1937)

S-C effect exists only for cone vision, not for rod vision. Because of the experimental procedure employed at Tiffany, cone vision was employed for brightnesses equal to or greater than 7×10^{-4} footlamberts. Since the greater part of the curves in Figures 1 and 2 correspond to brightnesses in the cone region, corrections for the S-C effect are obligatory.

Moon and Spencer** have shown that the S-C data for the fovea are test approximated by a parabolic function. These authors have integrated the function in order to compute the effective retinal illumination for pupils of various size. In order to convert the curves of Figures 1 and 2 to allow for the S-C effect, it is necessary to obtain factors expressing the reduction in retinal illumination resulting from the S-C effect with pupils of various sizes. Table III in the Moon and Spencer article represents the result of integrating the parabolic function. It expresses the amount by which the field brightness would have to be varied in order to obtain a constant retinal illumination with pupils of varying sizes. It is possible to obtain a factor for each pupillary area which expresses the relative "efficiency" of this area, expressed as the ratio of the effective retinal illumination obtained divided by the retinal illumination to be expected on the basis of area alone.

Moon and Spencer based their integration on the relative amount of S-C effect for each pupil area compared with the effect for a 2 millimeter pupil. For the purpose at hand, it is more useful to express the amount of S-C effect in terms of an "ideal" pupil of infinitely small area. Accordingly, the "efficiency" factors were expressed in terms of an "ideal" pupil with complete absence of S-C effect. Figure 3 presents "efficiency" factors as a function of pupillary diameter expressed in this way.

The data of Figures 1 and 2 can be corrected for the S-C effect by use of this graph. The procedure of correction is as follows: Values of the retinal illumination I are multiplied by the efficiency factors in Figure 3 appropriate to the pupil diameters obtained at each brightness. ($\Delta I \times \Omega$) values are likewise multiplied by the appropriate efficiency factors. The resulting curves are presented in Figures 4 and 5, representing the data of Tiffany Programs A and B, respectively.

**Moon, P. and D. E. Spencer, JOSA 34, 319-329 (1944)

These curves permit the immediate interpolation of Log ($\Delta I \times \Omega$) values for various values of retinal illumination. In this respect, the curves permit a very simple method of obtaining the interpolated data which are useful in the theoretical evaluation of binoculars. It should be emphasized that the data of Figures 4 and 5 represent more than 450,000 observations made under controlled laboratory conditions.

It is interesting to compare the data obtained at Tiffany with the corresponding data obtained at Brown University. At Brown, the observers scanned an orbit of approximately 18 degrees for a 30 second period. It would be expected, as a consequence, that the Brown data would represent a search time intermediary between Programs A and B of Tiffany.

In Figures 6 and 7, comparative data are plotted for the Tiffany and Brown experiments. In Figure 6, the Tiffany data have been interpolated from Figures 1 and 2 and do not include correction for the Stiles-Crawford effect. The Brown data represent the actual experimental points obtained, converted from 2360°K, the color temperature used, to 2850°K. The latter color temperature was used at Tiffany. Conversion was accomplished by means of the interpolated luminosity factors presented by Jones*. Figure 7 represents the corresponding data after correction has been made for the S-C effect.

Experiments were conducted at Tiffany to determine the functions relating stimulus exposure and threshold contrast for various brightness levels. It was found that at low brightnesses, a 30-second exposure produced minimal thresholds. As the brightness level was increased, however, a constantly increasing discrepancy between the 30-second threshold and the minimum threshold became apparent.

Corroborating the Tiffany experiment, the 30-second Brown thresholds are essentially equivalent to the minimum thresholds represented by Tiffany Program B at the lowest retinal illuminations. As retinal illumination increases, however, the 30-second thresholds become increasingly greater than the minimum thresholds. It is interesting to note that at the two highest illuminations, the Brown data fall nicely between the Tiffany data of Programs A and B.

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*Jones, L. A., "Summary of American Opinion, BS/ARP13, British Standard Specification for Fluorescent and Phosphorescent Paint." Gt. Britain Ministry of Home Security, RC (C)85, July, 1942.

In order to ascertain whether the shape of the functions in Figures 6 and 7 are the same for Tiffany and Brown data, adjustments were made in the absolute magnitude of the Brown ($\Delta I \times \Omega$) values to assure the best fit in each case. The data presented in Figures 8 and 9, indicate that when the Brown data are adjusted by a constant for best fit with the Tiffany Program B curves, very satisfactory agreement is obtained, whether or not correction is made for the S-C effect.

It is pertinent to compare the curves computed from the Tiffany data with the interpolated curves computed from the Brown data by special technique of OSRD Report No. 6099. Five retinal illumination levels were selected and interpolations were made from the Tiffany data of Program B and also from the Brown data by the special interpolation method. The data are presented in Figures 10 and 11, representing respectively the case where correction has not been made for the Stiles-Crawford effect and the case where such correction has been made. In each figure, reliable differences in absolute magnitude of log ($\Delta I \times \Omega$) values and also a significant difference in the shape of the curves are obtained.

The writer recommends that the Tiffany curves of Figures 3 and 4 be used for interpolations in future binocular evaluations since they represent a large number of experimental data. It may prove valuable to evaluate binoculars in terms of interpolations from both programs in order to investigate two widely separated values of stimulus duration.

FIGURE I: TIFFANY DATA - PROGRAM A

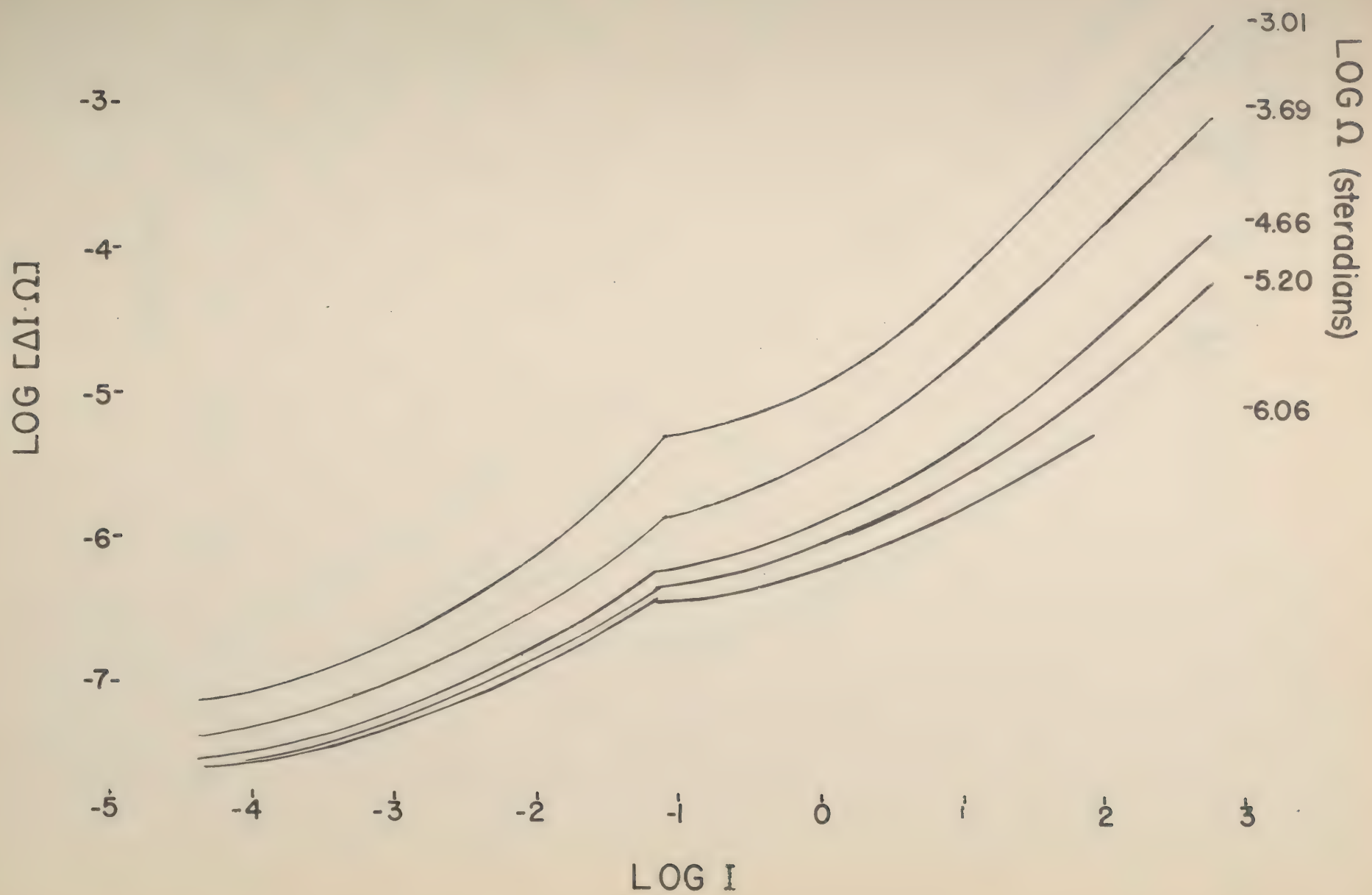


FIGURE 2: TIFFANY DATA - PROGRAM B

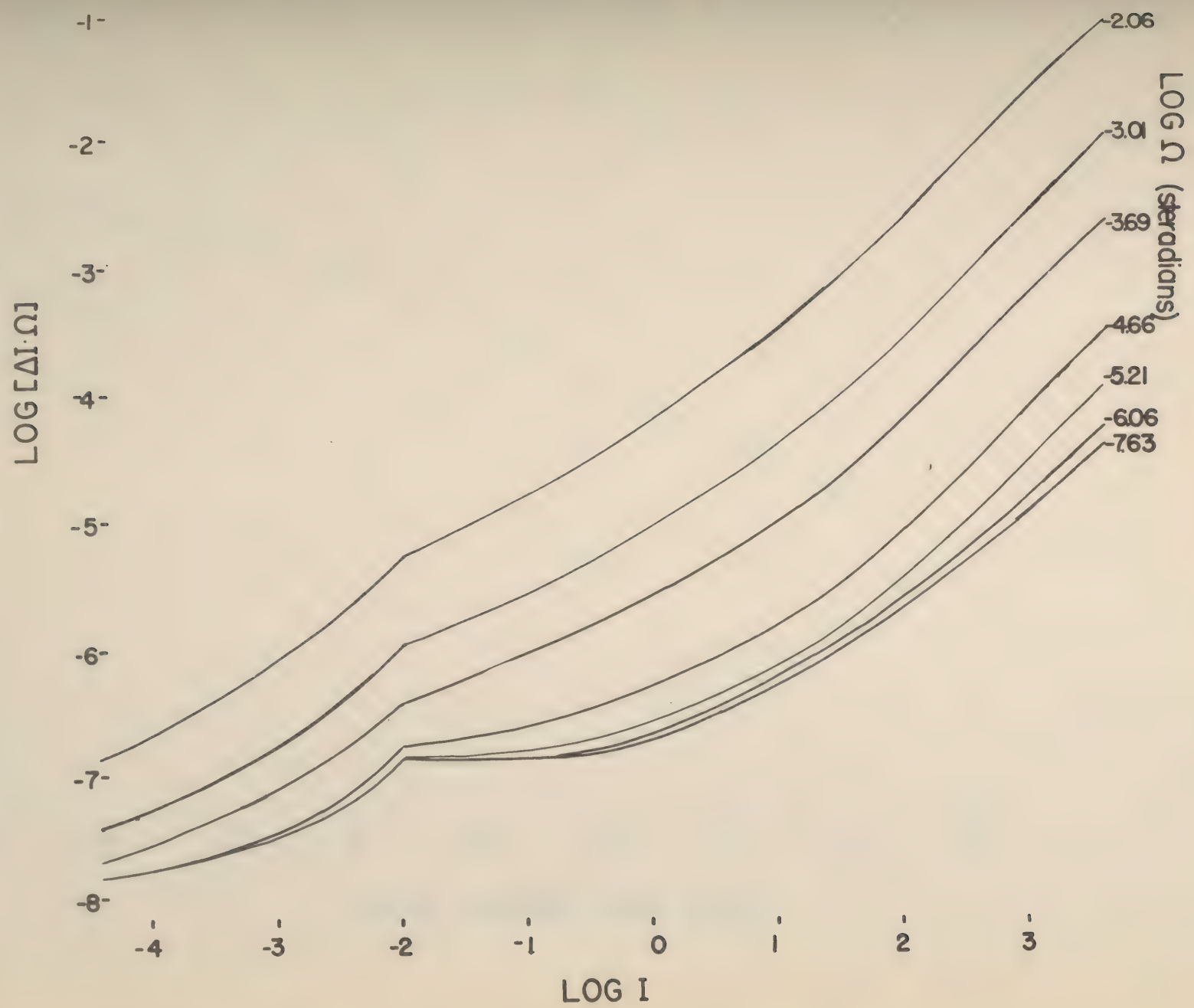


FIGURE 3: STILES-CRAWFORD CORRECTION FACTORS

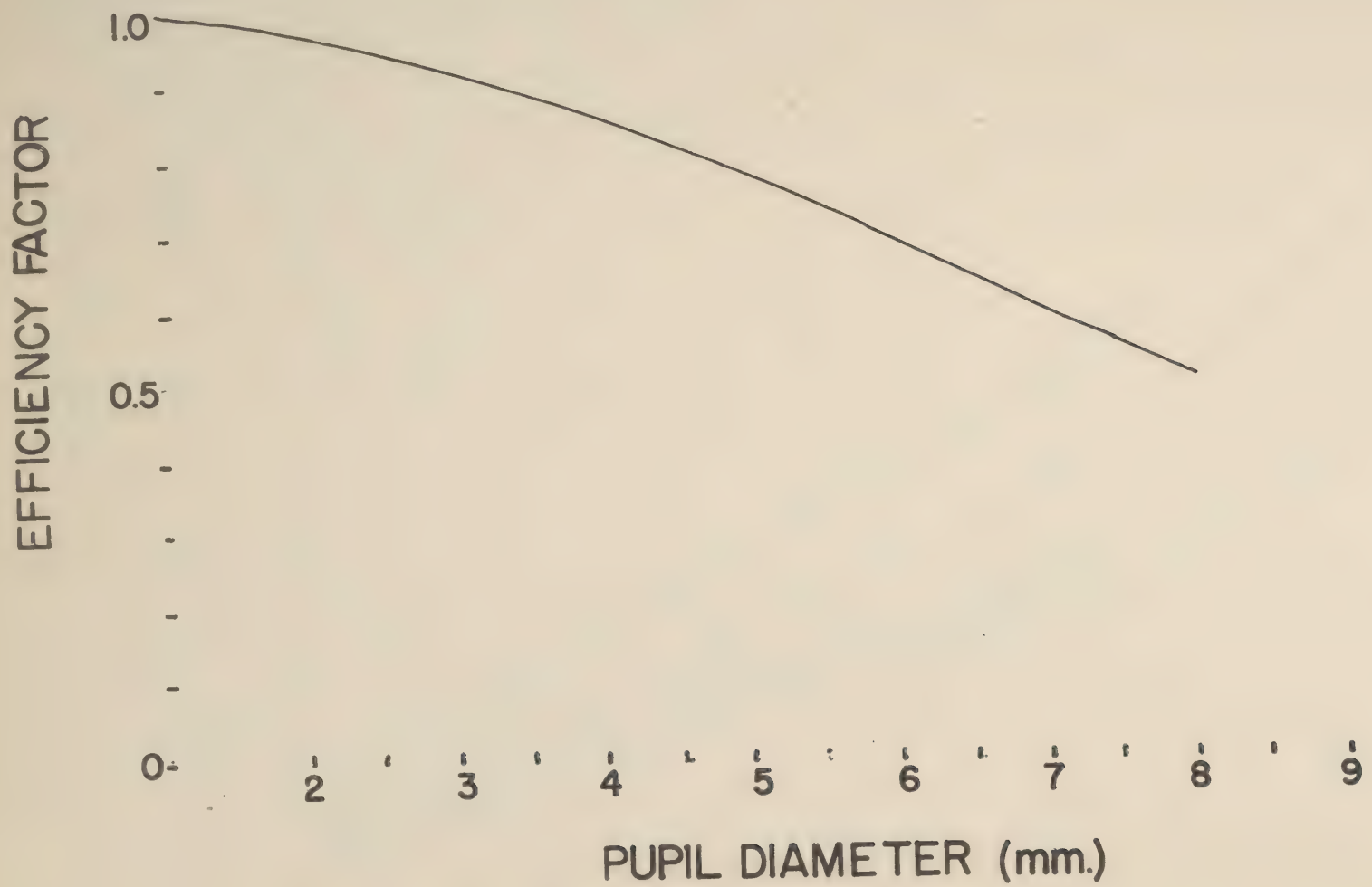


FIGURE 4: TIFFANY DATA - PROGRAM A

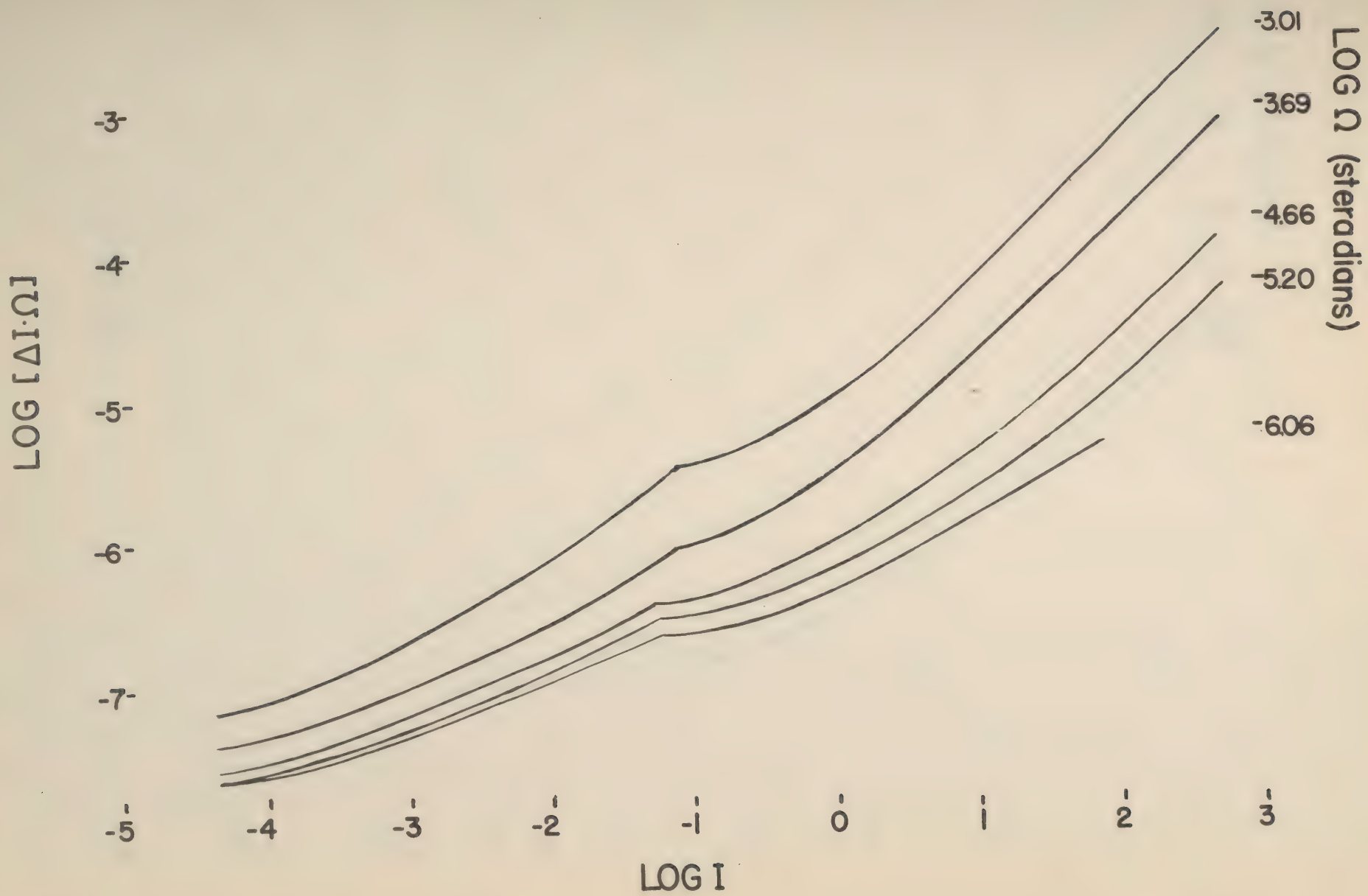


FIGURE 5: TIFFANY DATA- PROGRAM B

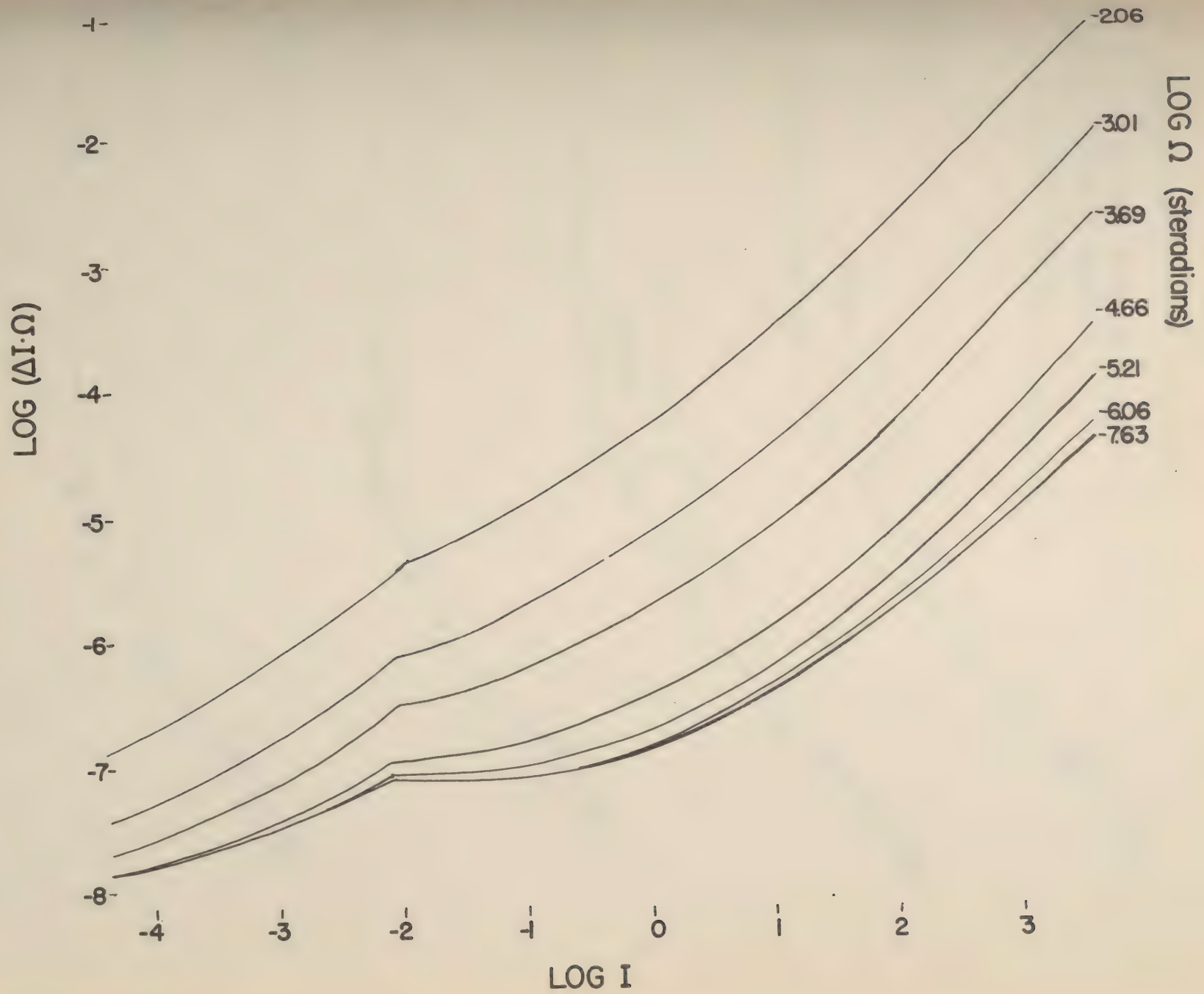


FIGURE 6: TIFFANY and BROWN DATA

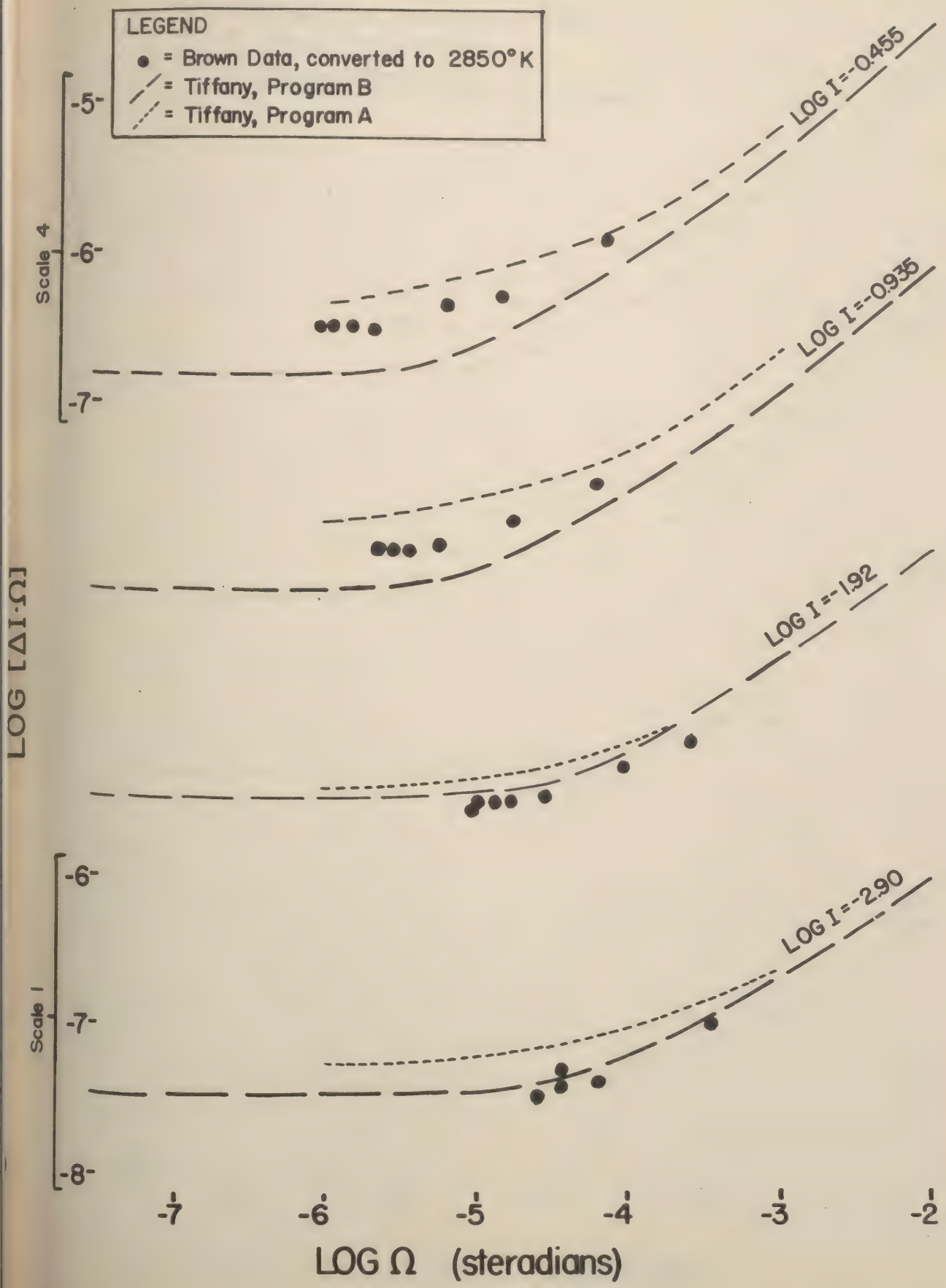


FIGURE 7: TIFFANY and BROWN DATA

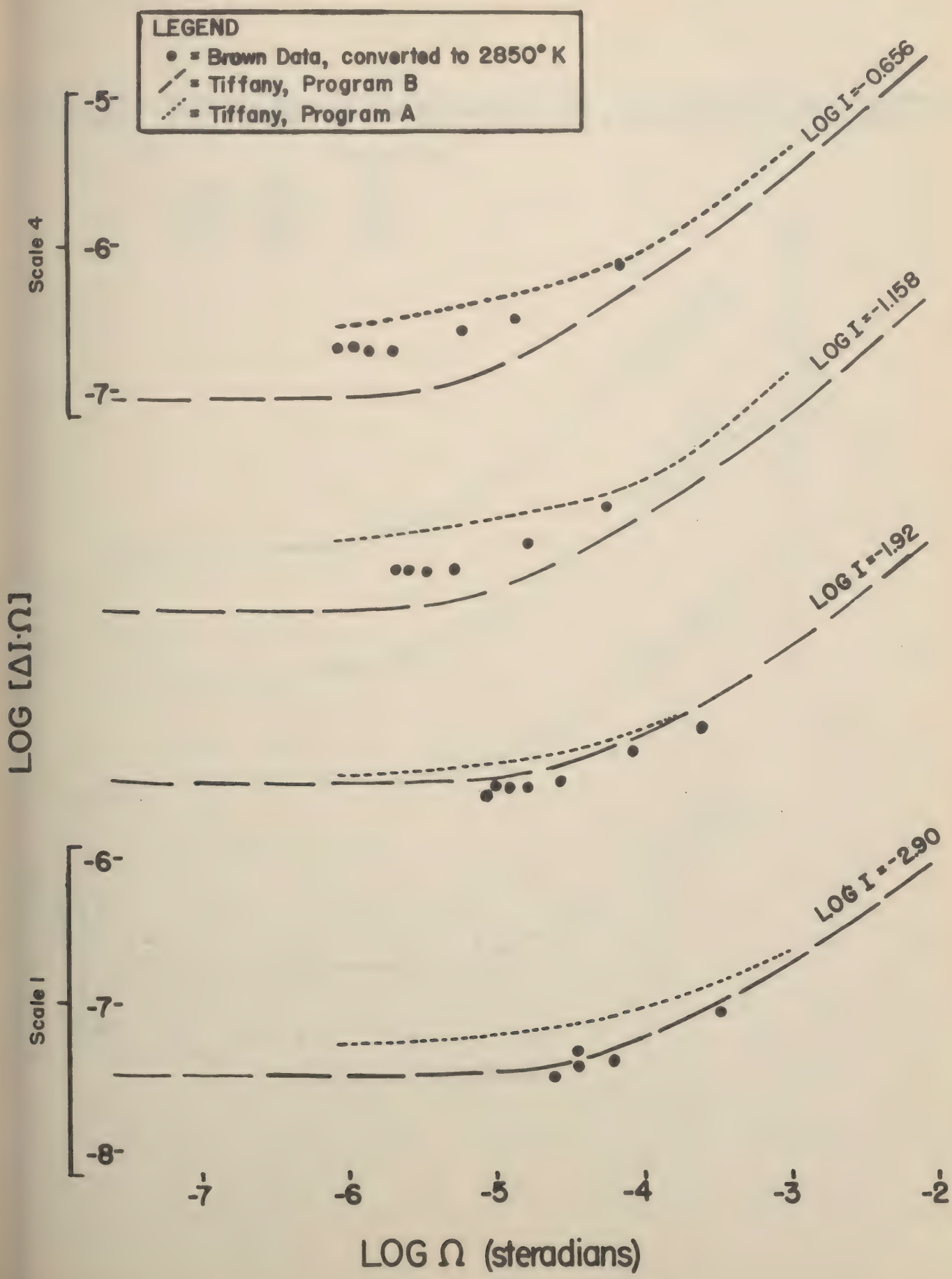


FIGURE 8: TIFFANY (PROGRAM B) and BROWN DATA

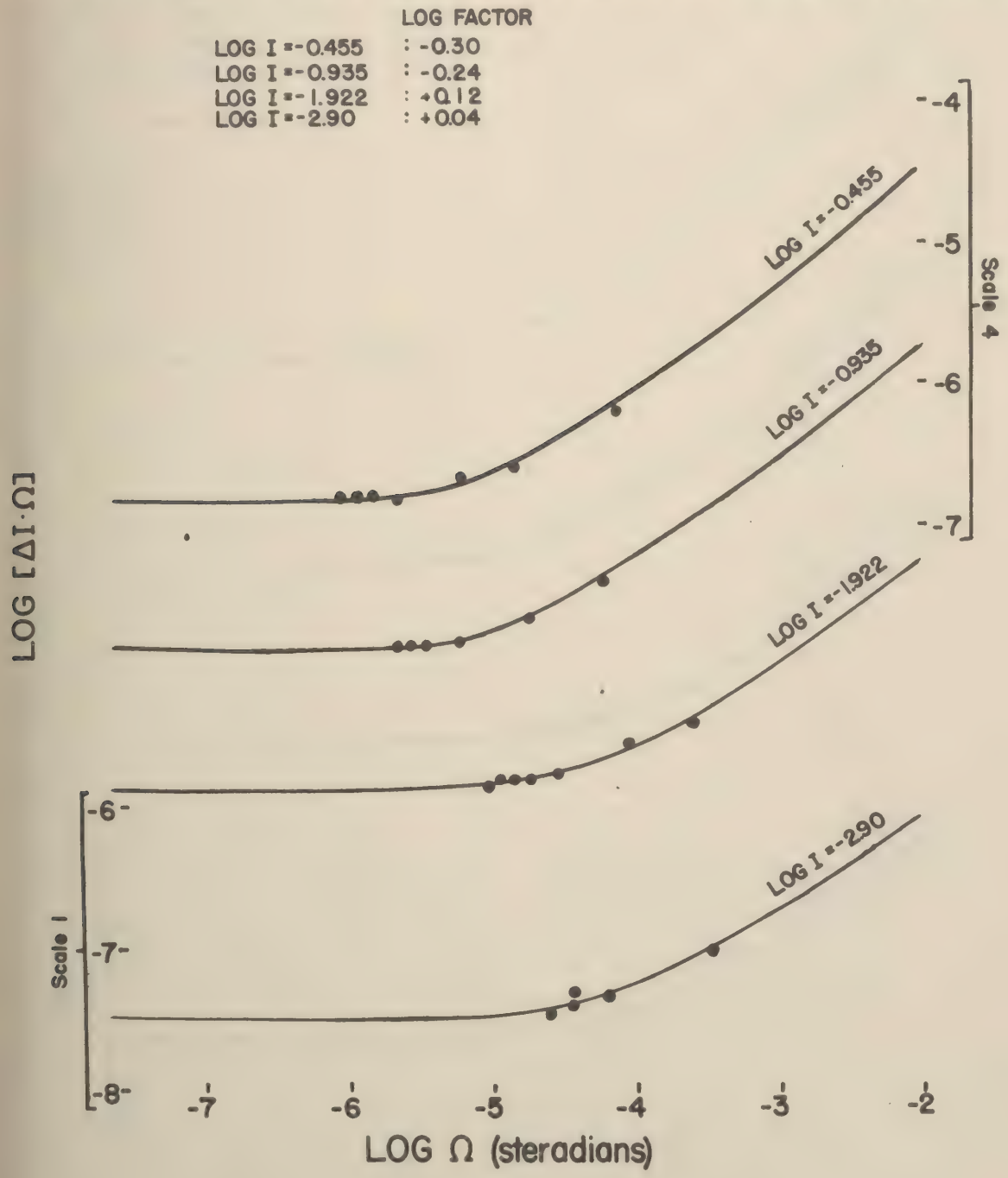


FIGURE 9: TIFFANY (PROGRAM B) and BROWN DATA

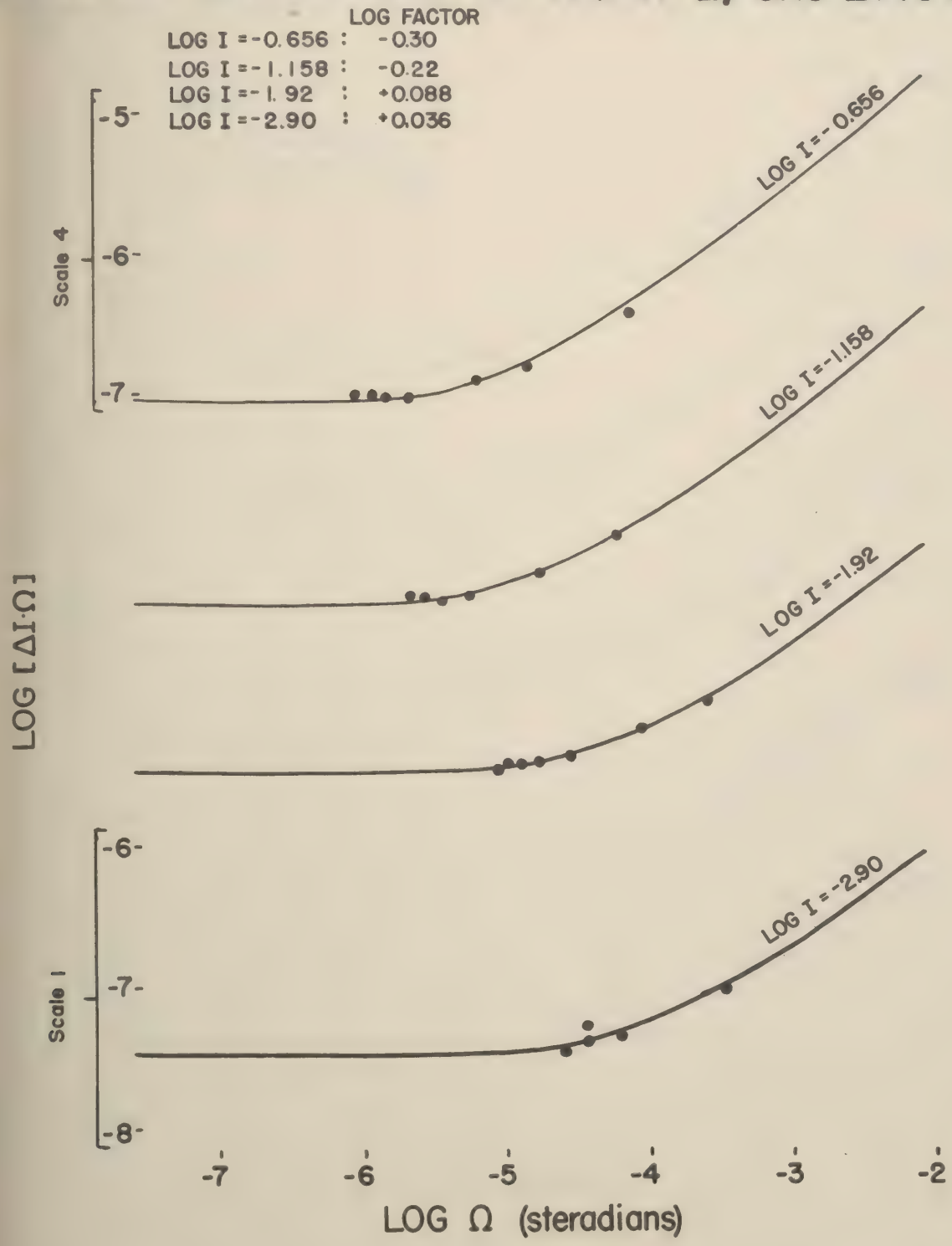


FIGURE 10: TIFFANY DATA and HARTLINE INTERPOLATIONS

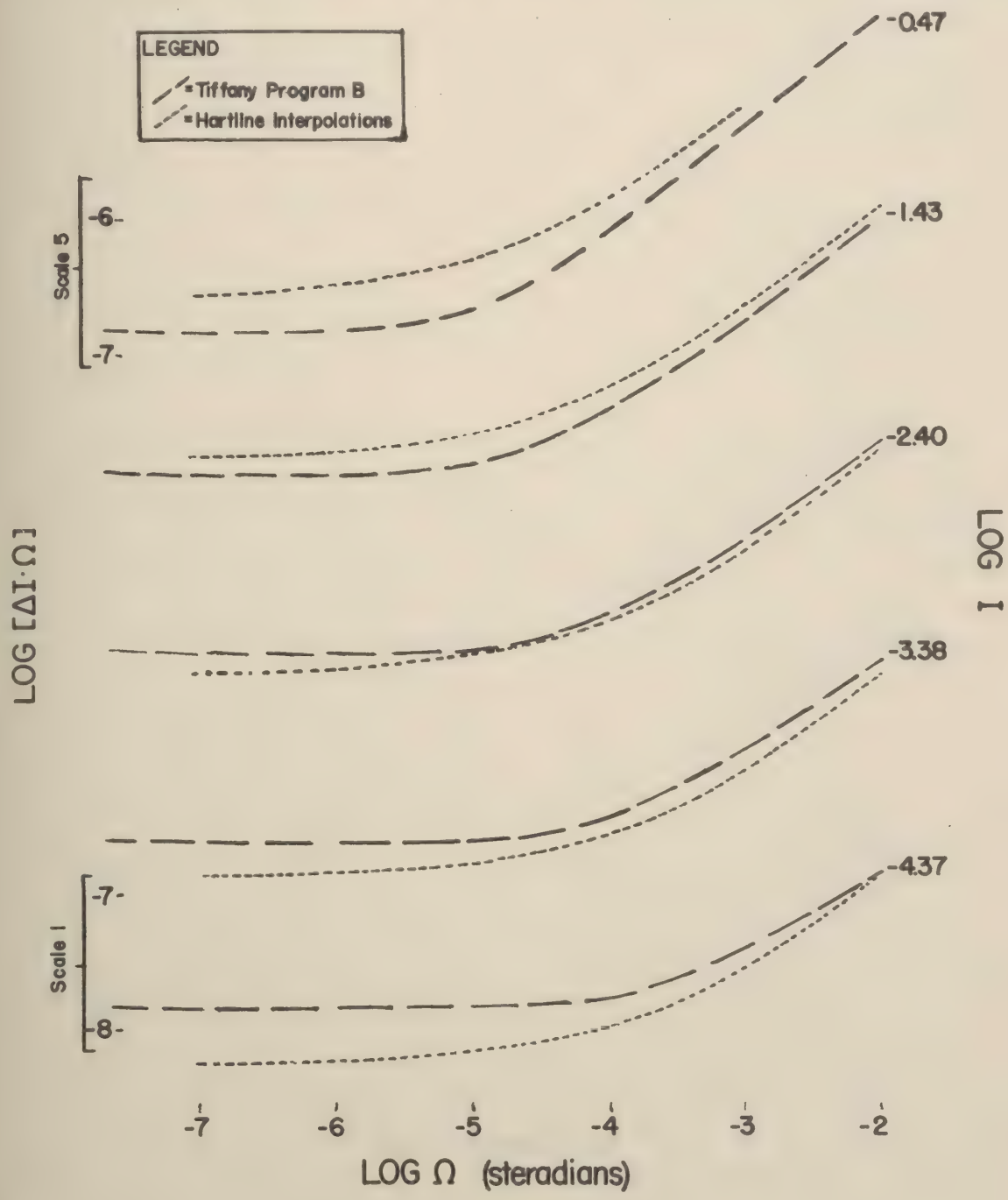
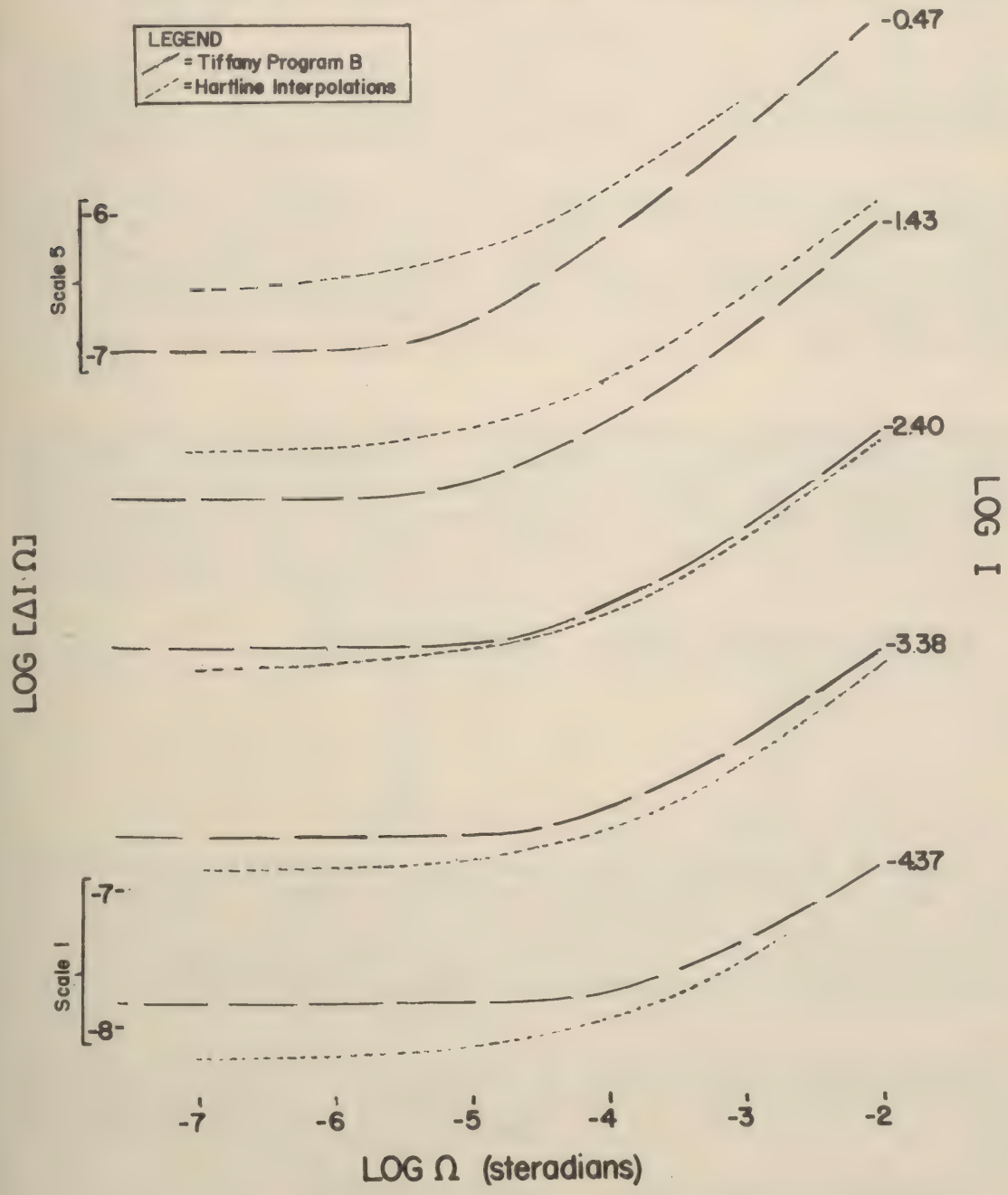


FIGURE 11: TIFFANY DATA and HARTLINE INTERPOLATIONS



ABSTRACTS

152. The Effects of Night Binocular Design Features on the Visibility of Targets at Low Levels of Illumination.
Miller, Carl W. and Lloyd H. Beck
Section 16.1 Report No. 150. OSRD Report No. 6128, October 25, 1945 69 pp. Open.

More than five hundred thousand observations are reported concerning the visibility of targets in the laboratory with the naked eye and with various binoculars.

A systematic study was made to determine the effect of exit pupil size upon the range at which visual detection occurs for five-power binoculars. Data for 2, 4, 6, 8, and 10 mm. exit pupils indicated that the range of detection increases markedly with larger exit pupil up to 5 or 6 mm., but that further increases in pupil exit resulted in small increases in range.

These data, together with data reported by Dartmouth College in OSRD No. 4433 made it desirable to attack directly the problem of the optimal compromise between exit pupil diameter and magnification in a binocular of prescribed aperture. Accordingly, the following series of binoculars of 50 mm. aperture was compared:

Magnification	Exit Pupil Diameter
5X	10 mm.
6	8.3
7	7
10	5
14	3.5

"Of these instruments, the best performance was obtained with the 10x50x7°. This binocular is an adaptation of the standard 7x50x7°, and has a special wide-field eyepiece designed by the Bausch and Lomb Optical Company. The range values obtained were close to 10% in excess of those given by the 7x50.

"In order to study binoculars of greater magnification and greater aperture, a similar series of instruments with 70 mm. objective diameter was studied:

Magnification	Exit Pupil Diameter
7X	10 mm.
8.5	8.3
10	7
14	5
20	3.5

"Each of these binoculars had the standard 10x70 body. The study of magnifications greater than 10^ involved many difficulties, and further investigation may be advisable. Under the conditions of the experiment, the best performance was obtained with the 10x70, which gave range values approximately 5% in excess of those obtained with the 10x50 widefield instrument. The 9x63 binocular, which was included in the study, gave approximately the same range values as the 10x70.

"The increase in aperture, which provides larger exit pupil with higher magnification, is of greater importance if the binocular is hand-held than if it is alidade mounted. All of the binoculars used in the program at Brown University were tested both as hand-held and as mounted instruments. Since all of the work was done under laboratory conditions in which vibration, roll, pitch, and wind were absent, and in two-hour observing sessions with frequent rest periods, the small gain afforded by mounting the binoculars on standard alidades is not unexpected."

153. Summary of Experimental Data.
Miller, Carl W. and Lloyd H. Beck
Section 16.1 Report No. 151, OSRD Report No. 6120,
October 25, 1945. Open

This report contains the original observer data for the extensive experiments reported in Abstract No. 152. The data indicate the total right and wrong choices each observer made when judging the location of a target of given size with or without the aid of binoculars.

154. Manual on the Pinhole Rectifying Camera.
Aero Service Corporation
Section 16.1 Report No. 156, OSRD Report No. 6100,
October 31, 1945 6pp, (R)

"A pinhole camera for rectifying high oblique aerial photographs was designed and constructed by this company at the request of Section 16.1 NDRC. It was intended for field use, in situations in which speed in producing a sketch map, with possibly only fair accuracy, is essential. Pre-design experiments had indicated that a pinhole camera would serve this purpose.

"The history of the development is given, the camera is described and a short manual for its operation is included. Test results are not shown since delivery of the camera was required before it could be tested."

155. Manual on the Variable Ratio Printer.
Aero Service Corporation
Section 16.1 Report No. 137, OSRD Report No. 6101,
October 31, 1945 11 pp, (R)

"A highly precise variable ratio projection camera, designed and constructed by this company at the request of Section 16.1 NDRC, is here described. This instrument is intended for use in a new system being developed for mapping from high oblique aerial photographs, in conjunction with other instruments constructed elsewhere.

"The history of the development and the specifications are given, the camera is described and a tentative manual of operation is included. Although the camera was tested for alignment and accuracy in our shop, a complete calibration and test cannot be made without the other instruments with which the camera is to be used. For this reason test results and a final, detailed operating manual are not included."

156. Physiological Factors Determining the Performance of Night Binoculars.
Johnson Research Foundation, University of Pennsylvania
Section 16.1 Report No. 135, OSRD Report No. 6099,
October 31, 1945 61 pp, Open

A study of the basic principles which operate to determine the usefulness of binoculars at night is presented, which has been found useful in predicting the effectiveness of various instruments. The contents of this report were presented at the 16th meeting of the Vision Committee. (A more complete summary of this material can be found on page 13 of this volume.)

Experimental eye guards for attachment to binoculars have been constructed, intended to reduce alignment errors and fatigue. In addition, an unconventional type binocular was constructed in which the optics were folded so as to bring the center of gravity of the instrument back of the eye position. This design was expected to reduce the angular unsteadiness as well as the fatigue.

157. The Penn State I-1 Michelson-Twyman Interferometer and Its Use in Determining Conformance with Design and in Quality Control of Lenses, Prisms, and Telescopic Systems.
Coleman, Howard S. and David O. Clark
Section 16.1 Report No. 142, OSRD Report No. 6106,
October 21, 1945. (R)

"This report describes the development of an interferometer of the Twyman-Michelson type and discusses its usefulness in the production and inspection of optical elements, subassemblies and complete systems, and in the development of new optical designs. The interpretation of fringe patterns in terms of standard aberrations is discussed. Numerous photographs show a close correlation between theoretical and experimental patterns, based on the use of special telescope systems which permit introduction of known amounts of spherical aberration, astigmatism and coma. These experimental systems were designed at the Yerkes Observatory, under Contract OEMsr-1078 and were constructed partly at Yerkes and partly at Penn State.

"Prior to the war the interferometer was used extensively in England for laboratory studies, and to a considerable degree for controlling production. The interferometer was used to a very limited extent in the United States before the war, but its use has become widespread in this country during the past five years.

"It seems unlikely that minute imperfections in the figure of most systems can be detected with greater accuracy by using the interferometer than by using the knife edge test, but for controlling production, and for inspection of optical elements and subassemblies, the interferometer has the great advantage that it shows errors over the entire aperture of a system at one time, on a quantitative and impersonal basis. It is possible that the interferometer will be very useful in controlling the production of aspherical surfaces, either by employing carefully figured aspherical end mirrors in the interferometer or by matching computed fringe patterns."

158. <u>A Description of the Kinetic Definition Chart (K.D.C.) Apparatus and Its Uses.</u>
Coleman, Howard S. and Samuel W. Harding
Section 16.1 Report No. 132, OSRD Report No. 6005, Oct. 19, 1945 : 82 pp, Open

"The K.D.C. Apparatus provides an impersonal method for measuring the resolving power of optical instruments with considerable precision. Different observers agree well in the score assigned to an instrument.

"It must be remembered, however, that a test of resolving power can give only a partial description of the overall performance of an optical instrument. Measures of scattered light are almost equally important. The curvature of field, astigmatism and color characteristics also have a marked influence on the effectiveness of an instrument."

"The Kinetic Definition Chart (K.D.C.) Apparatus, which is described in the present report, represents an extension of the work of Fabry, suitable for use under either laboratory or production conditions. A parallel-line Faucault test object is provided in which the apparent angular spacing may be varied continuously, either by changing the viewing distance (in the Model 2 K.D.C. Apparatus) or by moving the test object along the axis of a microscope objective which forms a minified image of the test object at the focus of a collimating lens (in the Model 4 K.D.C. Apparatus). The contrast may be changed, in discrete steps, by means of white rotating sectors directly in front of the target. The "K.D.C. efficiency" of an instrument is determined by measuring the limiting distance at which the test object can be resolved, first with the eye or an auxiliary telescope, and then with the eye or the same auxiliary telescope behind the instrument under test. If the instrument were optically perfect, the increase in distance would be exactly equal to the magnification. The 'K.D.C. efficiency' is expressed as the percentage ratio of the observed limiting distance to the theoretical limiting distance for resolution of the test object.

"Extensive experiments have been conducted to establish the conditions which yield the most consistent results and the most sensitive discrimination between instruments. It has been found that best results are obtained when an auxiliary telescope with approximately 15X magnification is used with 3X telescopes, that is, when the overall magnification is about 45X. When low contrast (10%) test objects are being examined, the overall magnification should be reduced to about 25X."

In conjunction with the K.D.C. Apparatus, observations were made to determine the angular resolution of the eye as a function of pupil diameter for an illumination of 473 footlamberts. It was shown that the increase in angular resolution to be expected from increases in pupil diameter in accordance with diffraction theory, is not fulfilled apparently because of aberrations in the outer zones of the lens and the final limitation produced by the structure of the retina.

159. Report on Optical Inspection.
Howard S. Coleman
Section 16.1 Report No. 139, OSRD Report No. 6103,
Oct. 20, 1945 135 pp, Open

"It is the purpose of this report to describe the general requirements indicated in optical specifications, the Government's methods of inspecting for conformance with those requirements, and to include a brief statement concerning the adequacy of the specifications and the inspection methods.

[redacted]

"As a result of the survey of optical inspection methods and of optical specifications, the following observations and conclusions may be made:

1. Optical Specifications should be revised so that nothing is specified that cannot be quantitatively expressed and measured.

2. Limitations imposed by design should be eliminated from specifications covering items under production.

3. Most of the difficulties of war time optical inspection are caused by a lack of trained inspectors, as the need for optical inspectors is practically nil in peace time as compared with the need during a war.

4. Inspection methods should be developed which are free from the influence of human judgment.

5. A sound philosophy should be established for the establishment of specifications and inspection methods.

6. Units of measurement and specification should be confined to either metric or engineering systems."

160. Visibility of Targets.
Louis Comfort Tiffany Foundation
Section 18.3, OSRD Report No. 6401, October 1, 1945,
69 pp, (R)

A report is given of the visibility data obtained by the Tiffany Foundation. The data reported herein are also contained in the Minutes and Proceedings of the 15th meeting of the Vision Committee, Pages 82 to 90.

161. Transient Color Phenomena in a Desert.
Louis Comfort Tiffany Foundation
Section 18.3, OSRD Report No. 6552, April 10, 1945,
31 pp, (R)

Investigations were undertaken to ascertain the cause of "transient color phenomena", observed in the desert. It had been reported that standard camouflage materials often behave in an unexpected manner when seen against desert landscapes.

[redacted]

[redacted]

"As a result of measurement and careful observation of colors of various materials and typical desert terrains, at various times of the day and for various weather conditions, it is concluded that:

"The colors of camouflage materials and of their terrain backgrounds undergo great changes as the conditions of lighting and observation change in the desert.

"These changes are all caused by optical phenomena of generally recognized and well understood character.

"The changes of the color of the background terrain are either not noticed or are severely underestimated by human observers, in a manner well known to psychologists and color photographers.

"The changes of color of camouflage materials are not recognized or are severely discounted as a consequence of the universal tendency to attribute a fixed color to any material, regardless of the color of the phase of daylight with which it may be illuminated.

"The changes of the colors can be of quite different kind for near-by objects than for distant backgrounds. Almost unnoticed changes of the individual colors can result in very apparent color contrasts. Such effects are much more likely to be noticed in the desert than elsewhere, because of the great distances which are commonly seen, and the clarity of the atmosphere which results in a very deep blue haze that causes the least possible interference with visibility but which does have important color effects.

"The mental conflict aroused by the appearance of an obvious color difference between an object and its background which were formerly matched and for each of which no color change has been noticed, is subconsciously resolved by the perception of a mysterious color component superimposed on only the near-by object. The visibility of the supposedly camouflaged object is then attributed to this mysterious added component.

"Distant scarf clouds, which may shadow distant terrains but be themselves invisible because hidden by the intervening blue haze, may produce lighting contrasts similar to those of sunrise and twilight. The resulting color contrasts may be very striking because of their sudden appearance without any visible cause. The optics of this situation is similar to that occurring with a low sun and both colorimetric problems can be handled by the same general procedure.

"No single camouflage treatment can be expected to conceal near-by objects against distant backgrounds at all times of day and for all weather conditions in the desert. The camouflage, however, can be designed so that optimum concealment

[redacted]

is afforded during the most critical hours and so that the extremes of color contrast occurring at other times are reduced to a minimum. Colorimetric procedures for the design of desert camouflage are proposed."

162. An Integrating Contrast Photometer.
Louis Comfort Tiffany Foundation
Section 16.3, OSRD Report No. 6553, July 24, 1945,
65 pp, (R)

In response to a request for information concerning the visibility of ships and aircraft a recording photoelectric integrating contrast photometer was constructed. This instrument was capable of determining the integrated (average) contrast between a model of the target and the sky directly above the horizon.

"After the integrating contrast photometer had been used by the Tiffany Foundation to measure models of submarines supplied by the Bureau of Ships and model aircraft supplied by the Bureau of Aeronautics, the instrument was moved to the U. S. Naval Air Station at Patuxent River, Maryland, where it is now in use by Navy personnel.

"The integrated contast between a target and the horizon sky depends upon the angle (θ) which the heading of the target makes with the line of sight of the observer and the angle (Ø) between his line of sight and the rays of the sun or moon. In any tactical situation, one of these angles is usually fixed, and the integrated contrast depends upon the remaining angle. In the interest of mechanical simplicity, the photometer described in this report was designed to produce a complete curve of contrast versus Ø for each value of θ. Obviously, data in the form of a complete family of such curves can be replotted as of a family of curves showing contrast versus θ for each value of Ø.

"Because time was at a premium when the construction of the integrating contrast photometer was undertaken, and because of the lack of electric power at High Hill, a relatively simple, semi-automatic photometer and curve tracer was constructed, rather than a completely automatic instrument requiring an alternating current supply for its operation."

163. Calibration and Use of the Spectrogeograph.
The Louis Comfort Tiffany Foundation
Section 16.3, OSRD Report No. 6555, Sept. 24, 1945,
73 pp, (R)

"A photographic instrument capable of measuring the quantity and spectral quality of radiant energy from natural daytime sources reaching an airplane during flight was designed and constructed by the Eastman Kodak Company under an OSRD Contract (OEMsr-717) supervised by this Section. The instrument has been described in OSRD Report No. 5444, entitled 'A Spectrograph for Aerial Use (The Spectrogeograph).' Although the Eastman Kodak Company was required under its contract to develop techniques for the use of the spectrogeograph, the contract also provided that 'the contractor shall not be required to use the instrument for obtaining data.' Consequently, the spectrogeograph was delivered to the Louis Comfort Tiffany Foundation, Oyster Bay, New York, where an OSRD contract for camouflage field studies was in force. On several occasions the Tiffany Foundation dispatched field expeditions to conduct flights with the spectrogeograph; and the data thus secured has been presented in a report entitled 'Reflectance of Natural Terrains.' (See Abstract No. 164). In the course of this field work, techniques for the calibration and use of the instrument were devised through the joint efforts of the staff of the Eastman Kodak Company and the staff of the Tiffany Foundation. This report describes the calibration of the spectrogeograph and illustrates many of the uses to which it may be put."

164. Reflectance of Natural Terrains.
The Louis Comfort Tiffany Foundation
Section 16.3, OSRD Report No. 6554, September 14, 1945, 64 pp, (R)

In order to undertake a fundamental study of the optical problems in camouflage, an airborne spectrophotometer was constructed. (See Abstract No. 163). This report contains the results of extensive flights over Florida and Southern California during the spring of 1944. The results are presented in the form of spectroradiometric and spectrophotometric curves of a large number of typical areas.

"In each case, the pair of curves is accompanied by an identification photograph of the terrain. A rectangle drawn on each identification photograph indicates the area of the ground which was imaged on the slit of the spectrogeograph at the instant of exposure, and an arrow indicates the exact portion of this area depicted by the curves. The photographs are black-and-white reproductions from original Aero Kodacolor Film. Since the original color pictures portray the terrain in a much more realistic manner, they have been preserved in the files of NDRC Section 16.3.

"A photographic instrument capable of measuring the quantity and spectral quality of radiant energy from natural daylight across reaching an airplane during flight was designed and constructed by the Eastman Kodak Company under an OSRD Contract (OEMsr-717) supervised by this Section. The instrument has been described in OSRD Report No. 6444, entitled 'A Spectrograph for Aerial Use (The Spectrogeograph).' Although the Eastman Kodak Company was required under its contract to develop techniques for the use of the spectrogeograph, the contract also provided that 'the contractor shall not be required to use the instrument for obtaining data.' Consequently, the spectrogeograph was delivered to the Louis Comfort Tiffany Foundation, Oyster Bay, New York, where an OSRD contract for camouflage field studies was in force. On several occasions the Tiffany Foundation dispatched field expeditions to conduct flights with the spectrogeograph; and the data thus secured has been presented in a report entitled 'Reflectance of Natural Terrains.' (See Abstract No. 164). In the course of this field work, techniques for the calibration and use of the instrument were devised through the joint efforts of the staff of the Eastman Kodak Company and the staff of the Tiffany Foundation. This report describes the calibration of the spectrogeograph and illustrates many of the uses to which it may be put."

164. Reflectance of Natural Terrains.
The Louis Comfort Tiffany Foundation
Section 16.3, OSRD Report No. 6664, September 14, 1944, 64 pp. (R)

In order to undertake a fundamental study of the optical problems in camouflage, an airborne spectrophotometer was constructed. (See Abstract No. 163). This report contains the results of extensive flights over Florida and Southern California during the spring of 1944. The results are presented in the form of spectroradiometric and spectrophotometric curves of a large number of typical areas.

"In each case, the pair of curves is accompanied by an identification photograph of the terrain. A rectangle drawn on each identification photograph indicates the area of the ground which was imaged on the slit of the spectrogeograph at the instant of exposure, and an arrow indicates the exact portion of this area depicted by the curves. The photographs are black-and-white reproductions from original Aero Kodacolor film. Since the original color pictures portray the terrain in a much more realistic manner, they have been preserved in the files of NDRC Section 16.3.